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CONTENTS

Measurement of Propeller Stresses in Flight . . . . . A. V. DEFOREST 227
Rational Shear Analysis of Box Girders . . . . . ROBERT S. HATCHER 233
The Reaction on a Body in a Compressible Fluid . . . . THEODORE THEODORSEN 239
A Radio Meteorograph System with Special Aeronautical Applications . . . . . H. DIAMOND, W. S. HINMAN, JR., AND F. W. DUNMORE 241
On the Strength of Columns that Fail by Twisting . . . . . EUGENE E. LUNDQUIST 249
Aerodynamic Factors in the Design of Long Range Flying Boats . . . B. C. BOULTON 254
The Balance of Vorticity in Parallel Shear Motion . . . . . C. L. PEKERIS 258
Torsion of 17ST Extruded Angles and Channels . . . . . LORETO LOMBARDI 260
Institute Notes 262
Letters to the Editor 259, 262
C. F. Taylor, J. C. Hunsaker, Joseph S. Newell

Exchanges 264
Aeronautical Reviews 265

Book Reviews

The Airplane and Its Engine, (*C. H. Chatfield, C. Fayette Taylor, and Shatswell Ober*) . . . Arthur Nutt 253
1937 Model Aeronautics Yearbook, (*Frank Zaic*) 253
Ships Aloft, (*Clayton Knight and Harold Platt*) 253
Ride on the Wind, (*Francis Chichester*) 272

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JOURNAL OF THE AERONAUTICAL SCIENCES

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Measurement of Propeller Stresses in Flight

A. V. DE FOREST, *Hamilton Standard Propellers Division, United Aircraft Corporation*

Presented at the Structural Problems in Aircraft Design Session, Fifth Annual Meeting, I. Ae. S. January 27, 1937

AS THE result of several years of research, Hamilton Standard Propellers has arrived at a practical solution of the difficult problem of measuring aircraft propeller stresses in flight, which should have useful applications in other fields. The obvious difficulties to be over come in continuously recording these stresses under all conditions have required the development of equipment and technique which should be easy to apply in other situations where space and weight are not at such a premium.

In the design of any engineering structure the first step is necessarily the establishment of the loads which the structure is to carry. Frequently, as in the case of bridges, buildings, ships, dams, and machinery where the new design does not depart radically from old and well-tried models, the structual elements are not calculated, but assumed by interpolation or extrapolation from the previous art. In this case the loads are not calculated as such, but are in general known to be below a certain limit of safety. How far below is seldom taken into consideration, for in most cases it is more economical to use a large factor of safety than to carry out a sufficiently careful study to eliminate the under-stressed material.

Where weight carries a penalty, as in rapidly moving machine parts and in airplane structures in general, it is important to learn as much as possible of the loading conditions so that the design may result in giving adequate strength to all parts with a minimum of parasitic weight. In no case is this more important than in the airplane propeller, where structural failure is inordinately expensive, and where excess weight not only is a burden to carry, but decreases the aerodynamic efficiency of the propeller blade.

When, about 1923, aluminum alloy blades came into use, it was soon realized that the blade was acting as a freely vibrating body, with stresses dependent on many different types of resonant vibration, and limited by the internal and external damping of the vibrating system.

Experience covering many types of engines, planes, and propellers, enabled the designers to meet various conditions, but without separating the various stress-raising types of vibration.

The most serious failures in propeller blades are those which occur close to the hub, for in this case the unbalance is usually so great as to tear the engine out of its mountings. The design of the shank and its attachment to the hub must, therefore, be especially considered. In order to study this portion of the blade, and to some extent the hub also, a heavy vibrating machine was built by Hamilton in 1930 (Fig. 1). This machine applies forced vibrations of $^{3}/_{8}$ inch amplitude at a frequency of 1750 per minute.

To compare the strength of various designs, a propeller of a type with a favorable service record is loaded with weights distributed along the blade, so adjusted that the natural period of the blade is not in resonance with the motion of the machine, but sufficient to break the blade in about 1,000,000 cycles. Other designs are then compared with this one and weaknesses at particular points may be corrected. As the stresses imposed are not the same as in service, due particularly to the absence of centrifugal loads, this test

FIG. 1. Forced vibration test machine.

is necessarily only a guide and must be supplemented by regular full-power engine tests. Obviously, the use of this machine, as well as other accelerated laboratory tests, can only be made complete by an actual knowledge of propeller stresses in service.

A research program was started in 1933 with two major objectives: first, means for measuring the important service stresses, and second, means for reproducing these stresses in the laboratory. The first objective seems now to have been successfully reached, and it is felt that the steps taken and the results obtained, may be of interest to others dealing with similar problems.

The constant loads on a propeller, those due to centrifugal force and air pressure, are possible of calculation and the strength of a propeller, subject to such loads, may be readily measured by a whirling test. Such tests, even at two or three times the designed power input, do not reproduce the failures which are met with in service.

The dynamic loads may be divided into two classes. First, those due to the varying air loads, obstructions of the slip stream, turbulence at the tips, etc. which would be present even with constant torque and no vibratory motion of the hub, and second, the forces due to torque variations and the varying motion of the centre of the hub in space. None of these dynamic forces cause important stresses except where their periods lead to one or more types of resonant vibration. It is well known that in a truly elastic body subject to resonant excitation, the stresses are rapidly built up to the elastic limit of the system, and are only limited by the external damping forces.

All metals have a certain amount of internal damping, in other words, are not truly elastic, and also there is a comparatively large loss of energy at fitted joints. Where the connections are simple, as in the fixed pitch propeller, there is less damping than in the variable pitch with its greater number of moving parts. The external damping due to the surrounding air is more important than the internal damping, but cannot be calculated without accurate knowledge of the amplitude frequency of the vibration. With this knowledge the effect of both internal and external damping can be properly investigated.

The exciting forces, apart from the aerodynamic ones already mentioned, are those resulting from the power plant and propeller combination. A complete list of all these effects is unnecessary, but the most obvious ones are listed for purposes of illustration.

(1) Torque variations in the driving force, especially when resonance occurs between a natural period of the crank shaft plus propeller and the power impulses.

(2) Fore and aft vibration of the propeller hub in space, either with or without a corresponding motion of the engine as a whole.

(3) Motion of the centre of the propeller hub in the vertical plane, such as produced by the centre of rotation not coinciding with the centre of gravity.

(4) A pitching or yawing motion of the propeller hub in space due to reciprocating and rotational unbalance.

A simple method of producing the various types of vibration which can produce resonance in the propeller was introduced in 1933. The blades, mounted in their hub, were suspended from an elastic sling and an air motor with an out-of-balance flywheel was attached to the hub. When the excitation is in resonance with any natural period, vibrations are set up which can easily be observed, their periods being measured from the rotational speed of the motor. The stress distribution under different modes of vibration can also be either calculated or measured. Also, stresses can be set up sufficient to break the propeller blade by fatigue at about the same locations and with the same appearance as those failures occurring in service, and furthermore, this stress could be set up by the expenditure of very little power.

The question then appeared to be, "Why do not all propellers fail, as some type of vibration must be in resonance during some portion of the engine's range?" To get any answer, it was necessary to find out what periods of vibration and what limiting stresses are excited during service condition.

From studies with the rotating flywheel, three general types of vibration can readily be identified. First: with the hub moving up and down with axis parallel, and blades flapping in phase with each other as do the winds of a flying bird. Second: the out of phase vibration where one blade is moving in the opposite direction from the other, the shape of the blades being the same in each case. The fundamental form of both types of vibration shows no blade element stationary in space, but at higher speeds, 1, 2, 3, or more stationary lines can be identified, corresponding to the first, second, and third harmonics. The positions of these lines of no motion are easily located with blades set at 0 pitch by the old system of

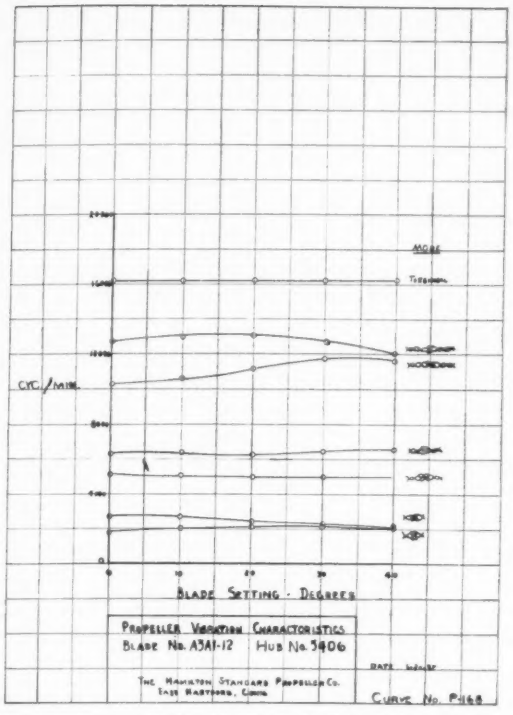

FIG. 2. Resonant vibration characteristics of a propeller with rotating flywheel excitation.

sprinkling light powder, for instance, sawdust, on the vibrating blade, showing nodes as in the well-known Chladni's figures on vibrating plates. The periods of the different forms of vibration are shown in Fig. 2. Third: torsional vibration of the blade about its longitudinal axis takes place at high frequency, about 20,000 cycles per minute, but the stresses associated with this form are probably low.

From the nomenclature applied to the vibration of wires fixed at both ends, the positions of no motion have been termed nodes, but it is to be particularly observed that the "node" nearest the end of the blade is not a position of zero stress as are the other true nodes where harmonics are present. In fact it is in reality close to a position of maximum stress.

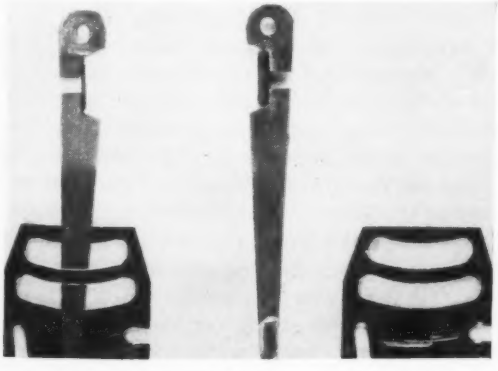

FIG. 3. deForest scratch gauge. Two inch gauge length.

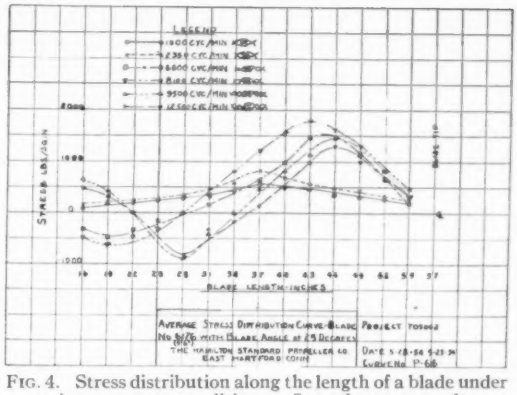

FIG. 4. Stress distribution along the length of a blade under various resonant conditions. Scratch gauge results.

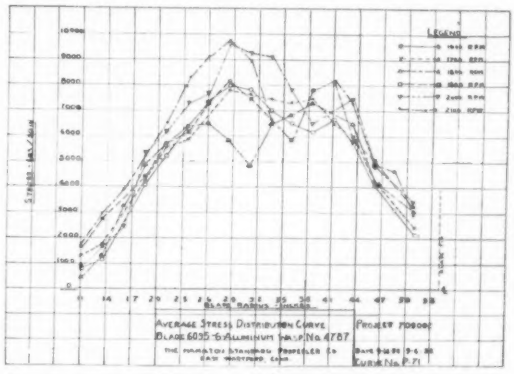

FIG. 5. Stresses in blade at different speeds on test stand. Wasp engine.

The rotating flywheel exciter is a most useful tool for the laboratory study of propeller vibration periods but the proper correlation with test stand and flight conditions is necessary to utilize the full possibilities of the test as a method for stress analysis. To do this requires either a knowledge of the modes of vibration in space of both the engine and the propeller, or a measurement of the local stress at each point of blade.

The measurement of local stresses seemed to be the easier problem, and a scratch recording strain gauge was developed which gave the actual strain over a 2 in. length, and was light enough to operate at high accelerations encountered near the propeller tip. This gauge was used on the propeller vibrated by the rotating flywheel and furnished good measurements from which to correct stresses calculated from the measured amplitude and mode of vibration. Fig. 3 shows the scratch gauge and Fig. 4 gives the stress distribution along the blade at various resonant frequencies. The curves in Fig. 5 give stresses on the test stand at various speeds. Examination of the scratch record shows more than a simple harmonic motion in nearly every case, so a direct relation between Figs. 4 and 5 is not possible. The scratch records give only maxima, and do not give frequency, wave form, or phase relation between different stations. Also, the scratch record does not cover a sufficient length of time to allow resonant

vibration to be recorded with certainty, unless some positive information is available as to when the record is to be started. Although stresses along the whole length of the blade for several hundred vibrations had been measured, there was no positive knowledge that under some other condition resonance would not occur. Also, even more important, there was no basis for identifying the particular engine vibration which excited the propeller under different speeds and power outputs.

What seemed needed was a continuous indication and record of local stress, acceleration, or displacement, with phase relations between the local motions and the cylinder explosions.

It is needless to elaborate on all the attempts to reach this goal, but many lessons were learned through failure, and are mentioned because of the general interest in vibration and stress measurement.

A series of tests were run on a direct optical method using small concave mirrors mounted at different points on the blades, each tracing a small circle on a screen in line with the centre line of the shaft. The resulting patterns were too complex for ready analysis.

Acoustic pick-ups were used, in conjunction with a General Electric sound analyzer; but this offered no solution of the local stress distribution.

Much work was carried on with various electrical strain gauges or accelerometers to be attached directly to the blades, the resulting indications carried through collector rings to an amplifier and oscillograph. A magnetic pick-up measuring rate of motion was built of sufficiently small dimensions to try out, and good records were made on the vibrator but the results require integration to be a measure of stress, and with complicated wave forms this is difficult if not impractical by ordinary methods. However, direct stress measurement is preferable to results derived from acceleration measurements, as it cannot be assumed that the engine vibration as a whole is negligible.

Another accelerometer was also tried, consisting of the device commonly used for producing sound vibrations directly in the bones of the head. This unit, after calibration, would work for a static vibration test, but was unsuitable for the high centrifugal loading of rotating propellers. The electrical system is closely akin to the electric torsiograph and requires an integrating circuit to give results in terms of stress. Accelerometers of the carbon disc type were tried, as were also small granular carbon microphones, but while frequency and phase relations were satisfactory, calibration was uncertain.

Piezo-electric and varying capacity methods were considered, but only the former was tried out. A commercial form of Rochelle salt pick-up, used in connection with electric reproduction of phonograph records, was called to our attention by Lycoming, and seemed suitable, but the units proved to be too delicate for use on engine-driven propellers. The piezo-electric pick-up is, however, very light and measures stress directly instead of in terms of acceleration. It has a very high energy output and is suitable for use with slip rings. In the presence of both torsion and bending, the stress analysis is complicated, as the device responds to both types of strain.

In 1936, a new line of experiment was opened up by E. H. Hull of the General Electric Company, who had successfully used the change in resistance of a strip of conducting paint under vibratory stresses.

In its first form, this pick-up consists of an insulating layer of paper cemented to the metal surface, and carrying lead-in contacts of tinfoil cemented to the upper surface of the insulating paper. The paint, applied between the two contact strips, was made of very finely divided graphite either in water or alcohol suspension.

The steady resistance of the strip varies in an irregular manner at zero load due to temperature, moisture and perhaps other disturbances. To avoid this difficulty, the strip was connected so that only the change in resistance with strain was measured. If the stress variation is above 300 cycles per minute, the amplifier only records the cyclic fluctuations and is not sensitive to slow changes in resistance.

Calibration of such strips at the General Electric Company, at Hamilton Standard Propeller, and at the Massachusetts Institute of Technology, showed that the measurement of strain was almost independent of frequency and closely proportional to strain amplitude. The resistance could be made quite high, 1000 to 50,000 ohms, and a considerable voltage applied to the system. In this way slip ring difficulties were largely avoided. The weight of the pick-up was infinitesimal and the measurement could be carried out anywhere on the blade, regardless of the centrifugal loading.

The major difficulties were the necessity for calibration of each paint strip under vibratory stresses, and the change in sensitivity due to temperature and moisture. The device is, in effect, an extreme refinement of the carbon pile telemeter as originally developed by Peters of the Bureau of Standards and marketed by Baldwin Southwark Company for the last ten years.

It seemed desirable to develop a very light strain-sensitive resistance unit which could be manufactured under reproducible conditions, calibrated, and attached to the propeller without the requirement of a dynamic calibration after attachment. The study of such methods was undertaken both at Hamilton and by the author at the Massachusetts Institute of Technology. One of these methods which showed good possibilities, was a mixture of sulphur and graphite with molded-in leads. The resistance was easily controlled and the dynamic sensitivity fairly stable. The resistance changes were sufficiently reproducible to lead us to hope that static calibration would be sufficient. How-

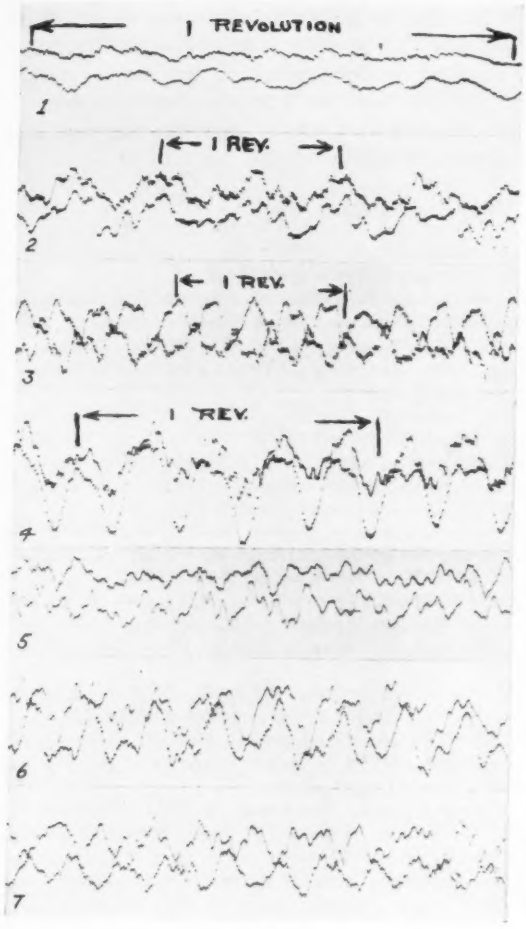

FIG. 6.

1. 1000 r.p.m. No resonance.
2. 1300 r.p.m. Test stand. In phase vibration. Stress ±3300 lbs. per sq. in.
3. 1400 r.p.m. Test stand. Out of phase vibration. Resonance with power impulses. Stress ±5000 lbs. per sq. in.
4. 1650 r.p.m. Test stand. In phase vibration. Resonance with power impulses. Stress ±6750 lbs. per sq. in.
5. 1900 r.p.m. Air. Take off. No resonance. Stress ±2500 lbs. per sq. in.
6. 1600 r.p.m. Air. Second harmonic in phase type vibration. Resonance with power impulses. Stress ±5000 lbs. per sq. in.
7. 2000 r.p.m. Air. Out of phase type vibration. Resonance with power impulses.

ever, the static behavior was not thoroughly satisfactory; the change in sensitivity, due to temperature, was troublesome; and the units were found difficult to attach and remove without changing to some extent the calibration.

Ultimately, a pick-up, which fulfilled the desired conditions to a degree which permitted a practical and accurate continuous recording of propeller stresses in flight, at any selected points of the hub and blades, was evolved in the form of a granular, baked carbon composition. These pick-ups proved to be stable to a high degree and could be calibrated under static loads

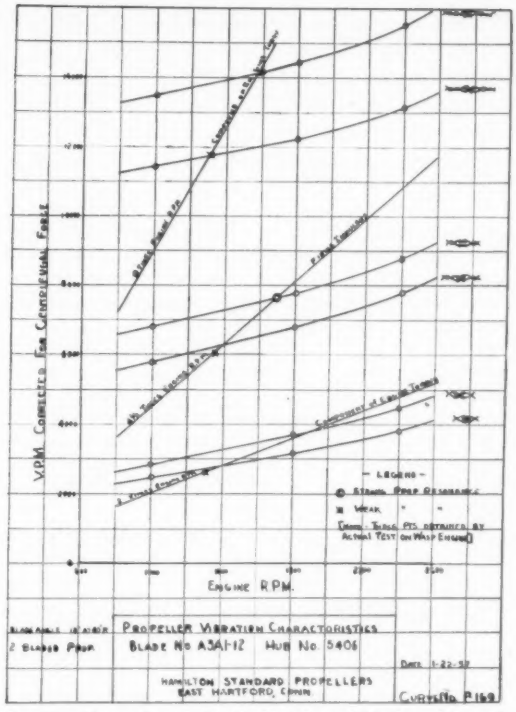

FIG. 7. Natural periods of vibration of blades with and without centrifugal load. Vibrations with rotating flywheel, and in flight.

in the laboratories and later transferred to vibrating members without too much change in calibration constant.

For example, using two pick-ups in corresponding positions on the opposite blades of a propeller, continuous studies of the various changes in modes of vibration and resulting stresses under any desired operating condition were possible. Fig. 6 shows two sets of oscillograph records taken under the foregoing conditions. In one case the propeller is on the test stand and in the other in flight. Resonant conditions of both the in-phase and the out-of-phase type of vibration are clearly shown. The change of resistance of the pick-up units is amplified and the records made using equipment developed by Draper at M.I.T. and built by Sperry.

Fig. 7 gives a plot of the natural periods of vibration of a pair of propeller blades with flywheel excitation and the same periods as indicated during flight. The necessary correction for centrifugal loading is here well indicated for the first time.

In some cases the tuning for resonance is broad, extending over a couple of hundred revolutions per minute, while in other cases the tuning is much sharper and suggests resonance between a propeller period and one of the forms of motion of the crank shaft. Much more investigation is necessary to locate the exciting forces under all conditions. In the first place, the motion of the engine in space must be considered

and in the second place, the various modes of vibration of the engine crank must be definitely known.

Suitable directional accelerometer units and torsional vibration units have been developed by Draper and Bentley of the Massachusetts Institute of Technology. It is to be expected that a combination of these instruments with dynamic strain measurements of all important parts of propeller and engine will lead to a much better understanding of the origin of propeller stresses than has heretofore been possible.

The attached bibliography indicates the work done by others in this field.

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Rational Shear Analysis of Box Girders*

ROBERT S. HATCHER, *Massachusetts Institute of Technology and U. S. Navy*

(Received February 17, 1937)

Summary

A SERIOUS obstacle to rational design of wings of the shell type has been the lack of a coordinated method of calculating stresses resulting from the bending, torsion, and shear loads present in the general case. Hence, in spite of the fact that a shell wing is a single structural unit, approximate methods have been used, in which the wing is split up into a number of fictitious "beams," and various modifications of the "elastic axis" conception have been tried.[1] Such methods have the apparent advantage of simplicity, in that they seem to evaluate the torsion couple and the bending distribution in a straightforward manner. The first obvious difficulty usually comes in the attempt to distribute the shear to the webs. That this is the only obvious difficulty does not imply that it is the only source of error, however, for any method which fails to take account of the elastic interactions of all the parts cannot lead to correct evaluation of the effects of either bending, shear, or torsion.

The following analysis attempts to demonstrate that the stress distribution in a single- or multiple-celled box girder under shear, torsion, and bending can be calculated without recourse to such approximations.

Heavily Stiffened Box Girder with Very Thin Webs

In this case it is assumed that the skin and shear webs are so thin as to have negligible effect on the bending properties of the girder. Fig. 1 shows the box girder discussed, with choice of axis, the XY plane being the supporting plane of the cantilever box. The force F represents the resultant of all vertical forces acting outboard of section a, b, c, d. The dimensions and properties of the section are indicated in Fig. 2. To avoid complications in dealing with principal axes of inertia, the Y-axis has been made a line of symmetry; it is therefore the neutral axis.[2] The heavy stiffeners at the corners are represented by their areas, A_1 and A_2, and the skin and web thicknesses by the letter t with subscripts. A further simplification is permissible if normal stresses in the webs may be neglected. Then shear stresses may be taken as constant between any two stiffeners. A later part of the analysis will consider the effect of webs capable of resisting bending stresses.

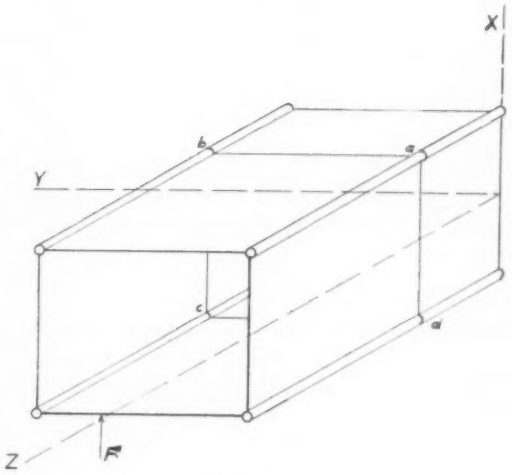


Fig. 1.

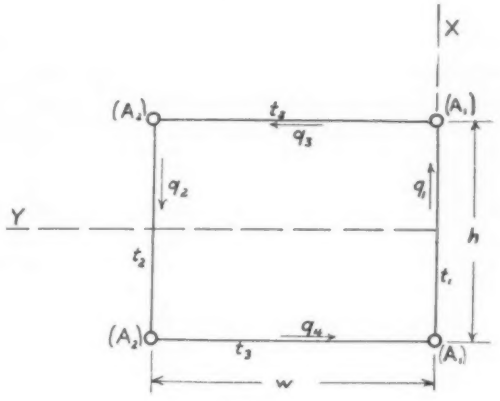


Fig. 2.

* The opinions or assertions contained herein are the private ones of the writer, and are not to be construed as official or as reflecting the views of the Navy Department or the naval service at large.

[1] An example of a common type of error occurs in Nagel's treatment of the subject (Felix Nagel, *A Method of Figuring Shear and Torsion in Multispar Wings*, Journal of the Aeronautical Sciences, Vol. 4, No. 1, November, 1936, pages 8–9). In the fifth equation, page 9, column 2, of that paper, $S = dM/dx$, where M is the bending moment in a single "beam" and S is the vertical shear in the web of that "beam." This relation is derivable from statics as a property of a loading curve and cannot be taken as defining the internal shear (stress resultant) of a single web in a complex web system. The principal effect of this error is omission of the important effect of shear in the horizontal webs or shear center location and general stress distribution.

[2] The fundamental Eqs. (1), (4), and (8) will be unchanged if OY is a principal axis, but not an axis of symmetry.

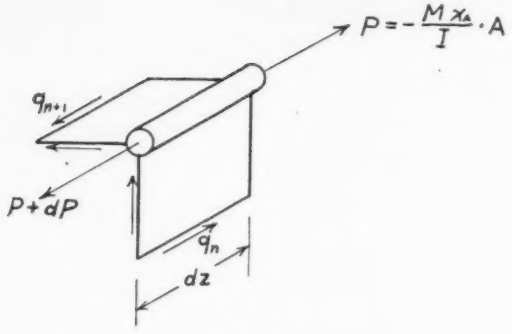


FIG. 3.

Considering now (Fig. 3) the length, dz, of the stiffener at a junction point of two webs, the condition of equilibrium parallel to OZ gives, after dividing by dz,

$$q_n t_n - q_{n+1} t_{n+1} = \frac{dP}{dz} \tag{a}$$

But, by the simple theory of bending,

$$P = -\frac{M x_A}{I} A \tag{b}$$

and

$$F = -\frac{dM}{dz} \tag{c}$$

In these equations, A is the area of the stiffener, and x_A its distance from OY taken positive upward; I is the moment of inertia of the girder section about OY, taken in this case as resulting from the stiffeners only.

Combining (a), (b), and (c)

$$q_n t_n - q_{n+1} t_{n+1} = \frac{F}{I} A x_A \tag{1}$$

Applying Eq. (1) to each of the four junction points of Fig. 2, and solving for the stresses, q, in terms of q_1 the following equations are obtained

$$\begin{aligned} q_3 &= q_1 \frac{t_1}{t_3} - \frac{F}{I}(A_1)\frac{h}{2}\frac{1}{t_3} \\ q_2 &= q_1 \frac{t_1}{t_2} - \frac{F}{I}(A_1 + A_2)\frac{h}{2}\frac{1}{t_2} \\ q_4 &= q_1 \frac{t_1}{t_3} - \frac{F}{I}(A_1)\frac{h}{2}\frac{1}{t_3} = q_3 \end{aligned} \tag{2}$$

The system of stresses (2) gives no resultant shear force in the horizontal direction; in the vertical direction the resultant shear acting on the section is

$$q_1 t_1 h - q_2 t_2 h = \frac{F}{I}(A_1 + A_2)\frac{h^2}{2} = F$$

Thus the requirements of general equilibrium are fully complied with.

The shear stress q_1 must have the value which makes the elastic energy a minimum. The normal stresses in the stiffeners are not affected by variations in q_1 if Eqs. (2) are satisfied; only the shear energy may therefore be considered

$$\frac{d}{dq_1}\sum \frac{q^2}{2G}\cdot t\cdot s = 0$$

whence

$$\sum q \cdot \frac{dq}{dq}\cdot t\cdot s = 0 \tag{3}$$

The summation (3) is taken around the entire section, the quantities, s, being the lengths of the various web or skin members. When equations of the type (2) are substituted into Eq. (3) it will be found that the following relation always holds:

$$\frac{dq}{dq_1}\cdot t = t_1$$

Eq. (3) thus becomes:

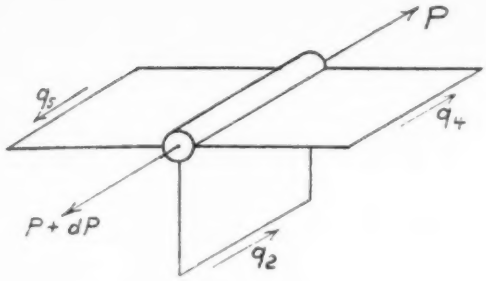
$$\sum q\cdot s = \odot \tag{4}$$

Applying Eq. (4) to the section, Fig. 2, and using Eq. (2), the shear stresses q are all determined (the symbol A here is used for $(A_1 + A_2)$):

$$\begin{aligned} q_1 &= \frac{F}{h}\cdot\frac{\frac{1}{t_2} + \frac{2w}{h}\cdot\frac{1}{t_3}\cdot\frac{A_1}{A}}{1 + \frac{t_1}{t_2} + \frac{2w}{h}\cdot\frac{t_1}{t_3}} \\ q_2 &= -\frac{F}{h}\cdot\frac{\frac{1}{t_2} + \frac{t_1}{t_2}\cdot\frac{1}{t_3}\cdot\frac{2w}{h}\cdot\frac{A_2}{A}}{1 + \frac{t_1}{t_2} + \frac{2w}{h}\cdot\frac{t_1}{t_3}} \\ q_3 = q_4 &= \frac{F}{h}\cdot\frac{\frac{1}{t_3}\left[\frac{t_1}{t_2} - \frac{A_1}{A}\left(1 + \frac{t_1}{t_2}\right)\right]}{1 + \frac{t_1}{t_2} + \frac{2w}{h}\cdot\frac{t_1}{t_3}} \end{aligned} \tag{5}$$

The resultant shear forces acting on the webs are, using the same subscripts:

$$\begin{aligned} S_1 &= F\cdot\frac{\frac{t_1}{t_2} + \frac{2w}{h}\cdot\frac{t_1}{t_3}\cdot\frac{A_1}{A}}{1 + \frac{t_1}{t_2} + \frac{2w}{h}\cdot\frac{t_1}{t_3}} \\ S_2 &= -F\cdot\frac{1 + \frac{2w}{h}\cdot\frac{t_1}{t_3}\cdot\frac{A_2}{A}}{1 + \frac{t_1}{t_2} + \frac{2w}{h}\cdot\frac{t_1}{t_3}} \\ S_3 = S_4 &= F\cdot\frac{w}{h}\cdot\frac{\frac{t_1}{t_2} - \frac{A_1}{A}\left(1 + \frac{t_1}{t_2}\right)}{1 + \frac{t_1}{t_2} + \frac{2w}{h}\cdot\frac{t_1}{t_3}} \end{aligned} \tag{6}$$



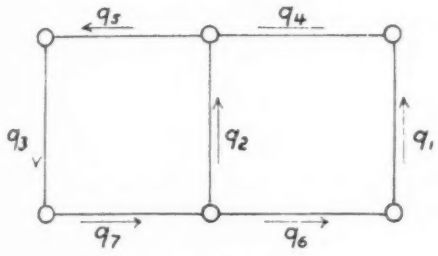


FIG. 4.

Eqs. (5) or (6) give the shear distribution on the assumption that the force F produces bending without torsion. To produce this result it must act along a certain line, passing through the center of shear of the section. Taking moments of the forces S about an arbitrary axis, and dividing by the total shear, F, the shear center is found to lie on the axis of symmetry and at a distance

$$\mathbf{y} = w\frac{A_2}{A}\left[1 + 2\cdot\frac{\dfrac{A_1}{A_2} - \dfrac{t_1}{t_2}}{1 + \dfrac{t_1}{t_2} + \dfrac{2w}{h}\cdot\dfrac{t_1}{t_3}}\right] \tag{7}$$

from the right hand side.

If the applied shear does not act through the shear center it produces a torsional couple equal to the product

$$T = F(\mathbf{y} - y_F)$$

where y_F locates the line of action of the applied shear. The principle of superposition permits the addition of the torsion shear stresses to the stresses Eq. (5), and the theory of torsion shows that the twist does not affect the normal stresses except at points close to a restrained end.

Examination of the last of Eqs. (6) shows that in the case of bending without torsion, there are shear stresses in the horizontal webs unless the relation

$$\frac{t_1}{t_2} = \frac{A_1}{A_2}$$

is satisfied. This relation also furnishes the only condition under which the shear center is at the "centroid of inertia" of the two side "beams." It is this effect which is usually neglected in calculating the "elastic axis" by approximate methods.

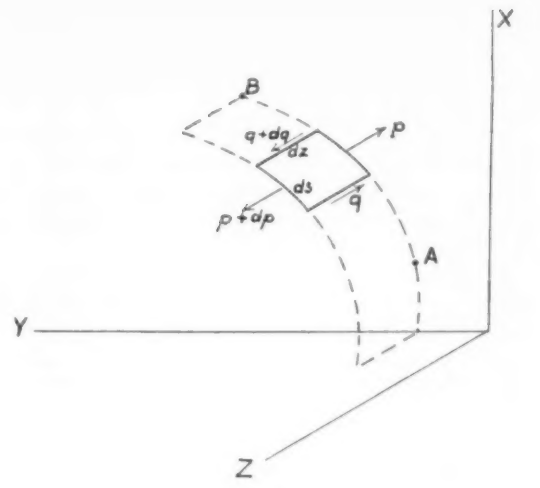


FIG. 5.

If the box girder consists of more than one cell, as in Fig. 4, the same methods are applicable, with slight modifications. For example, at the compound junction shown, the equation of the type (1) becomes

$$q_2 l_2 + q_4 l_4 - q_5 l_7 = \frac{F}{I} A x_A \tag{8}$$

It will be found that equations of types (1) and (8) will express all of the shear stresses in terms of any two of them; then Eq. (4) can be applied to two closed circuits, rendering all stresses determinate. On applying Eq. (4) to a closed circuit the terms $(q{\cdot}s)$ must be introduced with a negative sign if the indicated direction of the shear vector is opposed to the direction of movement in traversing the circuit in a counterclockwise direction.

Stiffened Box Girder with Webs Effective in Bending

If the webs of a box girder are effective in resisting part of the bending moment, the shear stress along the contour of the webs is no longer constant between junctions, but varies in such a manner as to introduce the normal stresses.

In Fig. 5 the arc AB is part of the contour of a box girder of arbitrary shape. The vectors p and q represent normal and shear stresses, respectively. The equilibrium of the element $ds \times dz$ of the web is assured by the equation

$$\frac{\partial p}{\partial z} + \frac{\partial q}{\partial s} = 0$$

From this

$$\frac{\partial q}{\partial s} = -\frac{\partial p}{\partial z} = -\frac{\partial}{\partial z}\left(-\frac{Mx}{I}\right) = -\frac{F}{I}x$$

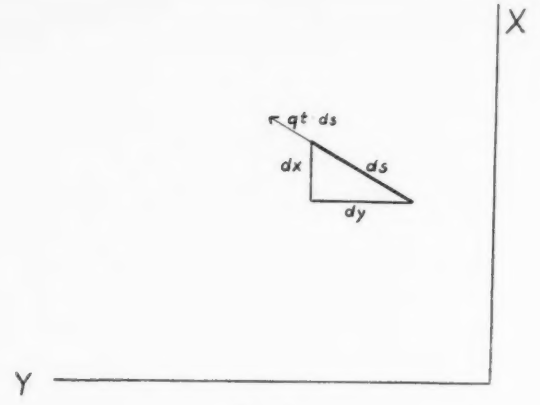


FIG. 6.

and, integrating between A and B,[3]

$$q_B = q_A - \frac{F}{I}\int_A^B x\,ds \tag{9}$$

Thus the shear stress at any point is referred to that at a fixed point as a function of the section properties. The integration is readily affected for many regular curves, and may be done graphically for any outline.

The shear-stress transition at a junction point is given by Eq. (1). Eqs. (1) and (9) therefore permit, in a box girder of one cell, the expression of all shear stresses in terms of one shear stress at an arbitrary fixed point.

This single stress, which may be called q_0, is found from the modification of Eq. (4)

$$\int_O q\,ds = 0 \tag{10}$$

Referring to Fig. 6, the vertical and horizontal components of the resultant shear on the section are, respectively:

$$\begin{aligned} F_v &= \int_O (q\,t\,ds)\frac{dx}{ds} = \int_O q\,t\,d\,x \\ F_H &= \int_O (q\,t\,ds)\frac{dy}{ds} = \int_O q\,t\,d\,y \end{aligned} \tag{11}$$

The clockwise moment about the origin of the resultant shear is

$$F\cdot\mathbf{y} = \int_O q\,t\,(y\,dx - x\,dy) \tag{12}$$

Broken up into two integrals, Eq. (12) is convenient for graphical integration where necessary.

As an example of the method, Fig. 7 is a re-drawing of the girder section of Figs. 1 and 2. The basic shear stress, q_0, is shown acting at the origin. By Eq. (9), the shear stress at any point in web EB is

$$q = q_0 - \frac{F}{I}\int_0^s x\cdot ds = q_0 - \frac{F}{I}\int_0^x x\cdot dx = q_0 - \frac{F}{I}\cdot\frac{x^2}{2}$$

The shear stress in web EB at joint B then is

[3] Eq. (9) is due to D. Williams, R. & M. No. 1669.

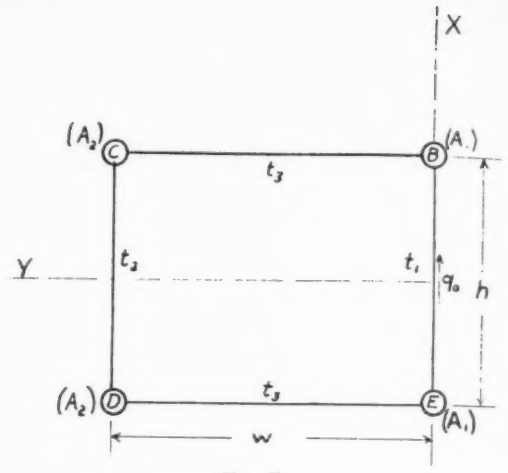


FIG. 7.

$$q_{-B} = q_0 - \frac{F}{I}\cdot\frac{h^2}{8}$$

And, by Eq. (1) the shear stress in web BC at joint B is

$$q_{+B} = \frac{t_1}{t_3}q_{-B} - \frac{A_1 h}{2t_3}\cdot\frac{F}{I} = \frac{t_1}{t_3}q_0 - \frac{F}{I}\left[\frac{t_1}{t_3}\cdot\frac{h^2}{8} + \frac{A_1 h}{2t_3}\right]$$

Proceeding in this way,

Side BC

$$q = \frac{t_1}{t_3}q_0 - \frac{F}{I}\left[\frac{t_1}{t_3}\cdot\frac{h^2}{8} + \frac{A_1 h}{2t_3} + \frac{h}{2}\cdot y\right]$$

$$q_C = \frac{t_1}{t_3}q_0 - \frac{F}{I}\left[\frac{t_1}{t_3}\cdot\frac{h^2}{8} + \frac{A_1 h}{2t_3} + \frac{hw}{2}\right]$$

Side CD

$$q_{+C} = \frac{t_1}{t_2}q_0 - \frac{F}{I}\left[\frac{t_1}{t_2}\cdot\frac{h^2}{8} + \frac{t_3}{t_2}\cdot\frac{hw}{2} + \frac{A_1 h}{2t_2} + \frac{A_2 h}{2t_2}\right]$$

$$q = \frac{t_1}{t_2}q_0 - \frac{F}{I}\left[\frac{t_1}{t_2}\cdot\frac{h^2}{8} + \frac{t_3}{t_2}\cdot\frac{hw}{2} + \frac{A_1 h}{2t_2} + \frac{A_2 h}{2t_2} - \frac{x^2}{2} + \frac{h^2}{8}\right]$$

$$q_{-D} = \frac{t_1}{t_2}q_0 - \frac{F}{I}\left[\frac{t_1}{t_2}\cdot\frac{h^2}{8} + \frac{t_3}{t_2}\cdot\frac{hw}{2} + \frac{A_1 h}{2t_2} + \frac{A_2 h}{2t_2}\right]$$

Side DE

$$q_{+D} = \frac{t_1}{t_3}q_0 - \frac{F}{I}\left[\frac{t_1}{t_3}\cdot\frac{h^2}{8} + \frac{hw}{2} + \frac{A_1 h}{2t_3}\right]$$

$$q = \frac{t_1}{t_3}q_0 - \frac{F}{I}\left[\frac{t_1}{t_3}\frac{h^2}{8} + \frac{A_1 h}{2t_3} + \frac{h}{2}y\right]$$

$$q_{-E} = \frac{t_1}{t_3}q_0 - \frac{F}{I}\left[\frac{t_1}{t_3}\frac{h^2}{8} + \frac{A_1 h}{2t_3}\right]$$

Application of Eq. (1) at joint E affords a check on the correctness of the work.

Applying Eq. (10), the result is:

$$q_0 = \frac{F}{I}\left[\frac{h^2}{8} + \frac{\dfrac{t_3}{t_2}\cdot\dfrac{hw}{2} + \dfrac{w^2}{2} + \dfrac{A_1 w}{t_3} + \dfrac{A_1 h}{2t_2} + \dfrac{A_2 h}{2t_2}}{1 + \dfrac{t_1}{t_2} + \dfrac{2w}{h}\cdot\dfrac{t_1}{t_3}}\right]$$

The resultant shears acting on the several webs are found to be:

$$S_1 = t_1\left[hq_0 - \frac{F}{I}\cdot\frac{h^3}{24}\right]$$

$$S_2 = t_1hq_0 - \frac{F}{I}\left[t_1\cdot\frac{h^3}{8} + t_2\cdot\frac{h^3}{12} + t_3\cdot\frac{h^2w}{2} + \frac{h^2}{2}(A_1 + A_2)\right] = S_1 - F$$

$$S_3 = S_4 = t_1wq_0 - \frac{F}{I}\left[t_1\cdot\frac{h^2w}{8} + \frac{A_1hw}{2} + t_3\cdot\frac{hw^2}{4}\right]$$

The total moment of shear stresses about the origin is

$$F\mathbf{y} = -2q_0t_1hw + \frac{F}{I}hw\left[\frac{h^2t_1}{4} + \frac{h^2t_2}{12} + \frac{3hwt_3}{4} + A_1h + A_2\cdot\frac{h}{2}\right]$$

As an illustration of the changes in shear distribution to be expected as a result of variations in web proportions, calculations have been made for four girders having the following properties common to all cases:

$$A_1 = 2$$
$$A_2 = 1$$
$$h = 10$$
$$w = 30$$

The web thicknesses used in the calculations were:

TABLE 1

Case	t_1	t_2	t_3
1	0.06	0.04	0.04
2	0.04	0.06	0.04
3	0.04	0.06	0.06
4	0.04	0.06	0.02

The results, assuming webs ineffective in bending, were:

TABLE 2

Case	I	S_1/F	$-S_2/F$	S_3/F	$\mathbf{y}/w$
1	150	0.65	0.35	−0.04	0.36
2	150	0.61	0.39	−0.17	0.45
3	150	0.59	0.41	−0.23	0.49
4	150	0.63	0.37	−0.06	0.40

The corresponding results, assuming webs capable of resisting bending, were, for the same four cases:

TABLE 3

Case	I	S_1/F	$-S_2/F$	S_3/F	$\mathbf{y}/w$
1	218	0.62	0.38	−0.01	0.38
2	218	0.56	0.44	−0.14	0.48
3	248	0.54	0.47	−0.18	0.53
4	188	0.60	0.40	−0.08	0.43

Sign Conventions and General Precautions

In the interest of clarity it is desirable to state explicitly a consistent set of sign conventions, which may be followed in any application of the principles outlined in Parts 2 and 3.

In dealing with a box girder subjected to any type of loading and support, the girder is assumed cut by a plane at the section which is to be investigated. Either one of the two parts so produced is imagined removed and replaced by a cantilever section acted on by a single force F which is the resultant of all forces applied to the section removed. This force F is taken as positive if directed upward. Positive bending moment causes the neutral plane to become concave upward; so that positive F and positive M go together.

The shear stresses q are considered to be those which act on the cut section of that portion of the girder which is not removed. In a single-cell girder these stresses are taken positive counter-clockwise. In a multiple-cell girder the stresses on the outer webs are positive counter-clockwise; the positive directions for the interior webs may be assigned arbitrarily if the equations of the type (8) are adjusted to correspond. A satisfactory method for multi-celled girders similar to Fig. 4 is to make all shear stresses on interior webs positive upward; then Eq. (8) can be written down by inspection for any junction.

In writing equations of the types (4), (9), or (10) it must be remembered that the adoption of a positive direction for q automatically imposes a similar positive direction for S, the length of arc. This introduces a negative sign where the direction of positive stress is opposed to the direction of counter-clockwise traverse of a circuit. The possibility of confusion is materially reduced if the circuit integrals (10) are always taken about closed circuits in which all the positive shear directions are counter-clockwise; then all quantities can be handled as in the single-cell girder.

The moment of inertia, I, must be taken to include all members which enter into the bending resistance of the section. In Part 2, only the stiffener areas were included. In Part 3, I included the web members, t_1, t_2, and t_3.

The Effect of Complete Lack of Symmetry of the Section

The fundamental equations developed in Parts 2 and 3 depend on the assumption that the simple law

$$p = -\frac{Mx}{I}$$

is complied with. This assumption is justified only if the axes OX and OY are principal axes of inertia of the section. In general the applied force F will be oblique to the principal axes; it will then be necessary to resolve F into its components, treating each separately.

In dealing with dis-symmetry of the section, the general Eqs. (1), (4), (8), (9), (10), (11), and (12) hold, provided that the quantity, x, is measured from a principal axis of inertia.

Conclusion

Two related methods of calculating shear distribution and shear center of single- or multiple-cell box girders have been presented. The analysis shows far from negligible effects of longitudinal stiffeners on the stress distribution and location of shear center.

The two methods should not be considered as independent; rather Part 2 should be considered as a simplification of Part 3. Further, it is not necessary to assume that all webs of a single girder behave alike; if certain webs are effective, and the others ineffective, in bending, the fundamental equations lead to a direct solution, if the following precautions are taken:

(a) The shear stress is constant in an "ineffective web."

(b) Eq. (9) governs the shear stress variation in an "effective web."

(c) I is the moment of inertia, about the principal axis, of all parts effective in bending.

This combined method enables one to deal with the effects of stress lag due to buckling or shear. For example, let it be assumed that the web, BC, of Fig. 7 is expected to buckle at 25 percent of the ultimate load, after which it acquires no increase in normal stress. Then the stress distributions may be calculated in two cases, in one of which BC is a variable shear web, and in the other it is a constant shear web; superposition of stresses for $F/4$ and $3F/4$ in the two cases then gives the final stress distribution and the center of shear for the girder, at the maximum load, F.

In this way it can be shown in certain cases that buckling of the webs of a box girder may change the magnitude of the applied torque.

Concurrently with the development of the theory of Parts 2 and 3, simple examples were worked out to demonstrate the application of the methods. The examples reduced to numerical form in Tables 1, 2, and 3 (for several combinations of web thicknesses) show variations of average web shear stresses of ten to twenty percent in the vertical webs and several hundred percent in the horizontal webs. The shear center was found to move through a range of positions covering 13 percent of the width of the box. Greater variations in all quantities might easily be obtained in specially selected sections.

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The Reaction on a Body in a Compressible Fluid

THEODORE THEODORSEN, *National Advisory Committee for Aeronautics*

Presented at the Fluid Mechanics Session, Fifth Annual Meeting, I. Ae. S. January 27, 1937

THIS paper specifically treats the problem of the reaction on a body in a stationary flow of a compressible fluid along lines devised by Lagally for the case of an incompressible flow. The results of this theoretical treatment show that a certain relationship exists; the reaction is in both cases dependent upon the singularities in the field of flow. A proof is given that the reaction on a body in a perfect compressible fluid is zero in a parallel flow; which is the d'Alembert paradox for compressible fluids.

Lagally[1] has shown that the force on a body in a non-compressible fluid depends on the singularities present in the fluid, or in other words on the distribution of sources and vorticity in the field of flow. In the following the forces on a body in a *compressible* flow in stationary motion shall be evaluated; thus generalizing the expressions of Lagally to include also compressible fluids.

The Euler equation of motion in vector form is given by

$$\frac{\partial \mathbf{q}}{\partial t} - [\mathbf{q}\ \text{curl}\ \mathbf{q}] = -\ \text{grad}\left(P + \frac{1}{2}\,\mathbf{q}^2\right)$$

where $\mathbf{q}$ is the velocity and $P = \int \frac{dp}{\rho}$

For steady motion $\partial \mathbf{q}/\partial t = 0$. Apply a system of external forces equal and opposite to the term $-[\mathbf{q}\ \text{curl}\ \mathbf{q}]$ in order to fix the vortices in the field.

There remains then

$$\text{grad}\left(P + \frac{1}{2}\,\mathbf{q}^2\right) = 0$$

or on introducing P

$$\text{grad}\ p + \frac{1}{2}\,\rho\ \text{grad}\ \mathbf{q}^2 = 0 \qquad (1)$$

The reaction on the body is evidently given as

$$\mathbf{R} = -\int_F \mathbf{p}\, d\,\mathbf{F} \qquad (2)$$

or also

$$\mathbf{R} = \int_V \text{grad}\ p\ d\ V - \int_S \mathbf{p}\, d\,\mathbf{S}$$

where S is an outer reference surface[2] surrounding V.

$$\mathbf{R} = -\frac{1}{2}\int_V \rho\ \text{grad}\ \mathbf{q}^2\ d\ V - \int_S p\, d\,\mathbf{S} \qquad (3)$$

But $$\text{grad}\ \mathbf{q}\cdot\mathbf{q} = 2(\mathbf{q}\ \text{grad})\mathbf{q} + 2[\mathbf{q}\ \text{rot}\ \mathbf{q}] \qquad (4)$$

Now develop the sum

$$(\mathbf{q}\ \text{grad})\mathbf{q} + \mathbf{q}\ \text{div}\ \mathbf{q} = Q$$

The X component is[3]

$$q_x \frac{\partial}{\partial x_x} q_x + q_y \frac{\partial}{\partial y} q_x + q_z \frac{\partial}{\partial_z} q_x + q_x \left(\frac{\partial}{\partial x} q_x + \frac{\partial}{\partial y} q_y + \frac{\partial}{\partial z} q_z\right)$$

which may be written

$$\frac{\partial}{\partial x} q_x q_x + \frac{\partial}{\partial y} q_x q_y + \frac{\partial}{\partial z} q_x q_z$$

Integrating this component multiplied by ρ throughout the volume V,

$\rho \dfrac{\partial}{\partial x} q_x q_x$ may be written:

$$\rho \frac{\partial}{\partial x} q_x q_x = \frac{\partial}{\partial x} \rho\ q_x q_x - q_x q_x \frac{\partial}{\partial x} \rho$$

The first component integrated therefore gives

$$\int_V \rho Q_x d\,V = \int_V \left\{\frac{\partial}{\partial x} \rho\ q_x q_x + \frac{\partial}{\partial y} \rho\ q_x q_y + \frac{\partial}{\partial z} \rho\ q_x q_z\right\} dx\, dy\, dz - \int_V \left\{q_x q_x \frac{\partial}{\partial x} \rho + q_x q_y \frac{\partial}{\partial y} \rho + q_x q_z \frac{\partial}{\partial z} \rho\right\} dx\, dy\, dz$$

The first integral reverts to a surface integral

$$\int_S \rho q_x (q_x\, dy\, dz + q_y\, dz\, dx + q_z\, dx\, dy) = \int_S \rho q_x (q_n\, dS)$$

This is the integrated x-component of the first integral. The total vector is

$$\int_S \rho \mathbf{q} (\mathbf{q}_n\, d\,\mathbf{S})$$

Now treat the second integral. This may be written

$$-\int_V q_x (\mathbf{q}\ \text{grad}\ \rho)\ d\ V$$

[1] M. Legally, Zeits. f. ang. Math. und Mech., 1922, S 409.

[2] The outer normal has been used as positive in this paper, also for the external reference surface.

[3] H. Peters of M.I.T. has pointed out that the final equation, Eq. (6), is conveniently obtained by retaining the vector analysis in the following.

which obviously is the x-component of the expression

$$-\int_V \mathbf{q}\,(\mathbf{q}\ \text{grad}\ \rho)\ d\ V$$

Thus as the final result

$$\int_V \rho\{(\mathbf{q}\ \text{grad})\mathbf{q} + \mathbf{q}\ \text{div}\ \mathbf{q}\}dV =$$

$$\int_S \rho\ \mathbf{q}\ (\mathbf{q}_n d\mathbf{S}) - \int_V \mathbf{q}\ (\mathbf{q}\ \text{grad}\ \rho)\ d\ V \qquad (5)$$

By use of Eqs. (2), (3), (4), and (5) the reaction is obtained as

$$\mathbf{R} = \int_V \{\rho\mathbf{q}\text{div}\ \mathbf{q} - \rho[\mathbf{q}\ \text{rot}\ \mathbf{q}] + \mathbf{q}\ (\mathbf{q}\ \text{grad}\ \rho)\}dV -$$

$$\int_S \{\rho\ \mathbf{q}\ (\mathbf{q}_n\ d\mathbf{S}) + p\ d\ \mathbf{S}\}$$

But $\quad \mathbf{q}\ \rho\ \text{div}\ \mathbf{q} + \mathbf{q}(\mathbf{q}\ \text{grad}\ \rho) = \mathbf{q}\ \text{div}\ (\rho\mathbf{q})$

Then finally:

$$\mathbf{R} = \int_V \{\mathbf{q}\ \text{div}\ \rho\mathbf{q} - \rho[\mathbf{q}\ \text{rot}\ \mathbf{q}]\}\ dV -$$

$$\int_S \{\rho\ \mathbf{q}\ (\mathbf{q}_n\ d\ \mathbf{S}) + p\ d\ \mathbf{S}\} \qquad (6)$$

The outer reference surface S may be put conveniently at infinity. If now the *sinks and the sources in the field of flow are equal in magnitude* it is known that the velocity q at infinity approaches a constant, or $q = q_\infty$ + quantities proportional to less than the second power of $(1/r)$ where r is the distance from the origin. The same consideration holds for the pressure p, which is easy to show.

The first part of the surface integral becomes then:

$$-q_\infty \int \rho\ \mathbf{q}_n\ d\mathbf{S}$$

which is equal to

$$-q_\infty \int_V \text{div}\ (\rho\mathbf{q})dV$$

which integral is equal to zero, since the net sum of the sinks and sources is zero.[4] The second part of the integral $\int_S p d\mathbf{S}$ is also zero since q deviates from a constant by terms no larger than $(1/r)^3$.

Thus the reaction on a body in a parallel compressible flow with no excess of sources over sinks is obtained as

$$R = \int_V \{\mathbf{q}\ \text{div}\ \rho\ \mathbf{q}) - \rho\ [\mathbf{q}\ \text{rot}\ \mathbf{q}]\}d\ V \qquad (7)$$

Lagally's expression for the similar case with $\rho = \rho_0 =$ constant is

$$R = \rho_0 \int_V \{\mathbf{q}\ \text{div}\ \mathbf{q} - [\mathbf{q}\ \text{rot}\ \mathbf{q}]\}\ d\ V$$

If the source intensity everywhere is zero div $(\rho\mathbf{q}) = 0$ for a compressible flow, just as div $\mathbf{q} = 0$ for a non-compressible flow. If the rot $\mathbf{q}$ also is zero everywhere, we obtain $\mathbf{R} = 0$ in both cases.

Thus the general proof for the d'Alembert's paradox for a compressible flow has been obtained: *a body in a frictionless compressible fluid in translatory motion experiences no drag.* The term "frictionless" is of far reaching importance. It is for instance to be noticed that, if at any local point the velocity of sound is exceeded, the stationary field pattern will actually move relative to the stream at super-sound velocity. There will be a resulting entropy increase and the conditions specified in this analysis will not be satisfied. The effects of ordinary friction and heat transmission are more obvious. If a hypothetical fluid existed which was perfectly "adiabatic" a "stationary" flow could not in general exist at super-sound velocities. The scope of the present paper shall not be extended, but it is interesting to note that the acting *moments* which in general do not become zero can be developed along similar lines. The moments on a body in a compressible flow differ from those in the non-compressible flow.

[4] Div (ρq) is always zero for the flow representing the body itself.

A Radio Meteorograph System with Special Aeronautical Applications*

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Introduction

THIS paper describes a precision radio meteorograph system developed by the Radio Section of the National Bureau of Standards for use in the Meteorological Service of the U. S. Navy Department. The work was begun at the request of the Navy Department and was directed to meet the requirements formulated by that Department. Initial tests of the system indicate that it is likely to meet the requirements quite closely.

The complete radio meteorograph system consists of transmitting and instrumental means for sending down from unmanned balloons meteorological observations on upper-air pressure, temperature, and humidity, receiving and recording equipment on the ground for automatically plotting these data in the graphical form desired by meteorologists, and direction finding means (also at the ground station) for tracking the flight of the balloon so as to determine upper-air wind speeds and directions.

The balloon instrument consists of a radio transmitting unit, a battery unit, and a meteorograph unit. The latter contains the elements which vary in accordance with barometric pressure, temperature, and humidity. In one form of this instrument means are provided for the measurement of light intensity, thereby giving data on the height and vertical structure of cloud formations through which it passes.

The complete instrument is contained in a balsawood container 6 × 6 × $4^1/_2$ inches with separate compartments for each of the three units. (See Fig. 1.) The total weight is $1^3/_4$ lbs. in the current design. The radio transmitter employs three receiving tubes of the 2-volt filament type, one serving as a special audio oscillator, the second as an audio amplifier, and the third as an ultra-high-frequency oscillator. The meteorograph unit is electrically connected to the audio oscillator. Special light-weight batteries provide sufficient power for efficient operation of the transmitter for over two hours under flight conditions.

Carrier frequencies ranging up to 200 megacycles per second have been used in tests of the radio meteorograph system. The transmitter shown in Fig. 1 employs a carrier frequency of about 50 megacycles per second and feeds its power into a half-wave transmitting antenna. Satisfactory records have been obtained from this type of transmitter with the balloon carried away by upper-air winds to distances of the order of 150 miles from the ground station.

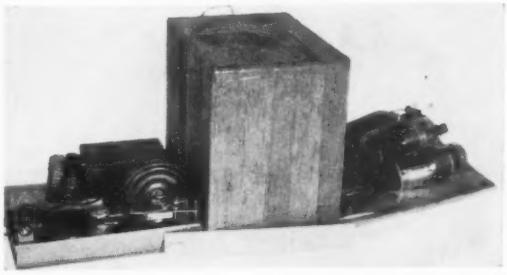

FIG. 1. Complete radio meteorograph showing the radio transmitter, batteries, meteorograph unit, and balsawood box in which they are assembled.

The operating requirements for this instrument as set forth by the Navy Department were quite rigid. The instrument was to have a unit cost of about $25 in reasonable quantities, weight as close to one pound as feasible, and provide pressure indications in the range of from 1000 to 200 millibars with an accuracy of indication of one millibar, temperature indications in the range of from +30° to −70° C. accurate to within one degree, and humidity indications in the range of from 0 to 100 percent relative humidity accurate to within 3 percent. Consideration was to be given in the design to the provision of emitted signals suitable for use by radio direction finders on the ground in order to permit determination of upper-air wind speeds and directions. To comply with these requirements, it was found necessary to develop a new method of switching the radio transmitter to provide a sequence of radio signals which may be interpreted at the ground station to give a measure of the pressures, temperatures, and humidities encountered. The essential feature of this method is that it employs no rotating parts. Practically all other radio meteorographs use a clockwork, fan, electric motor, or some other source of motive power to accomplish this function.

To obviate the need for such motive power, advantage is taken in this method of the fact that the barometric pressure element deflects continuously in one direction as the balloon ascends. A pointer actuated by the pressure diaphragm moves over a simple switch-

* Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

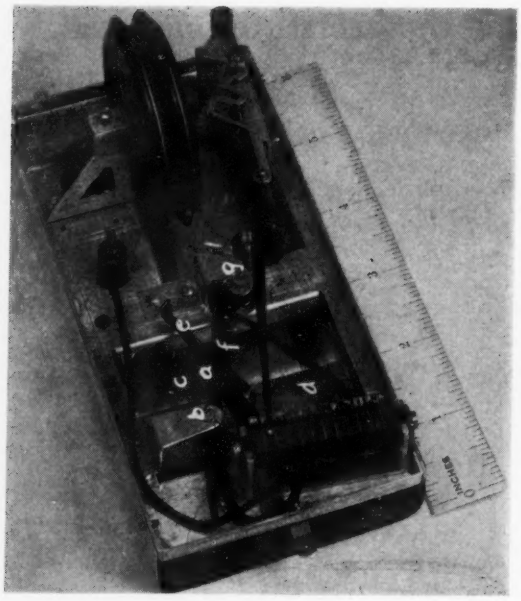

FIG. 2. Front view of experimental meteorograph unit.

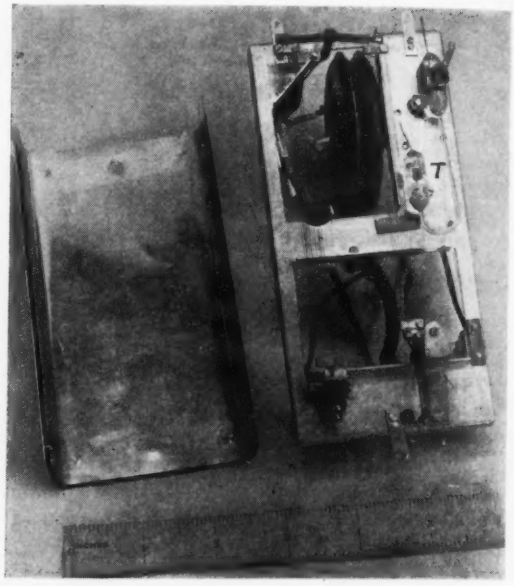

FIG. 3. Rear view of meteorograph unit.

ing element which consists of alternate conducting and insulating segments. As the arm moves over these segments it performs the necessary switching operations. The face of the switching element is polished so that friction opposing the arm movement is negligible. Hence, the sequence of switching operations also serves to mark definite values of pressure on an absolute scale. Successive fifth conducting segments of the switching element provide positive identification of the portion of the pressure range which is being indicated. How thees identifying contacts function and also the manner in which the temperature and humidity indications are given will be described in the following sections.

The pressure-switching arrangement affords several important advantages over other types of meteorographs:

(1) It provides absolute readings of that meteorological element which requires the greatest precision of measurement, *i.e.*, the barometric pressure.

(2) By dispensing with the need for auxiliary motive power for switching it makes possible a very simple and inexpensive meteorograph unit, an essential feature if the radio meteorograph is to replace the use of airplanes in this service.

(3) The number of observations obtained during an ascent becomes independent of the rate of ascent of the balloon. Hence, a high rate of ascent may be used in order to reduce the total time required for taking a complete set of observations. To take full advantage of this feature, a special temperature device is incorporated in the meteorograph which responds much faster to temperature changes than the conventional bi-metallic thermometer. It consists of a small capillary tube filled with a sulphuric acid solution of 1300 specific gravity. The resistance of this tube changes markedly with temperature and serves to change the transmitted signal in a manner which will be explained later. Satisfactory progress has also been made toward the development of a device to replace the conventional sluggish hair hygrometer universally employed for indicating humidity.

(4) The record provided at the ground station with this method automatically plots temperature and humidity as abscissas against pressure as ordinates, a form of graph preferred by meteorologists consulted.

THE METHOD OF PRESSURE SWITCHING

The operation of the pressure-switching method may be more fully understood by reference to Figs. 2, 3, and 4. Figs. 2 and 3 show two views of an experimental meteorograph unit while Fig. 4 shows the electrical connection of this unit to the audio oscillator of the radio transmitting set. The output of the audio oscillator is amplified and then serves to modulate the ultra-high-frequency carrier output of the transmitter. The audio oscillator is of special design so that its frequency may be controlled by the value of resistance connected in its grid circuit. This permits the use of a combination of fixed and variable resistances in the pressure-switching circuit for securing identification of the pressure scale and for producing modulation frequencies which are proportional to the temperatures and humidities encountered.

Referring to Fig. 2, the pressure diaphragm, linkage and arm are clearly shown. The end of the pressure arm (see also *P* at Fig. 4) carries a platinum tip which slides over the polished surface of the switching ele-

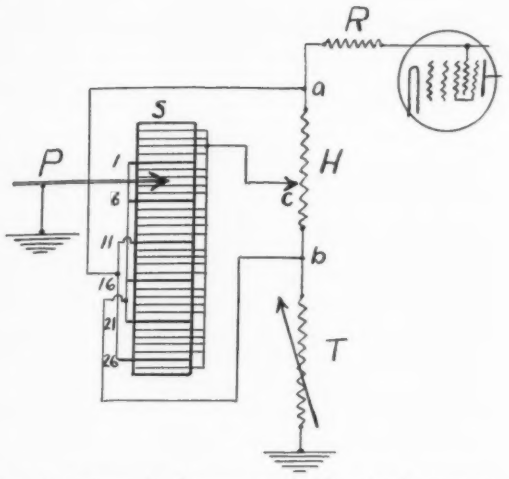

FIG. 4. Schematic of pressure-switching circuit arrangement.

ment. The conducting segments of the switching element stand out in the photograph as white lines, particularly the index contacts which are of greater thickness. The conducting segments are of coin silver 0.003 inch thick and the insulating segments of bakelite 0.015 inch thick. Double or triple segments are used for the index contacts, as desired.

The arrangement used for giving humidity indications is also shown in Fig. 2. The small metal cam a is swung about the shaft b by two hair elements operating in series (c and d). The free end of this cam is connected by the spring e to the free end of a second cam f. The other end of the cam f pivots about the shaft g. Cam f is formed simply by bending a wire-wound resistor into the desired shape. As the cam a moves under the action of the hair hygrometer, the cam resistor f is forced to follow it due to the spring. A rolling contact is thereby obtained between the metal cam and the resistor. This contact moves from one end of the resistor to the other as the relative humidity varies from 0 to 100 percent.

A view of the other side of the meteorograph unit with the radiation shield removed is shown in Fig. 3. The hair drive for the metal cam is somewhat more clearly shown. Note also the location of the temperature capillary tube at T.

Referring now to Fig. 4, consider first how the pressure indications are given. Contact of the pressure arm P with any given conducting strip of the switching element S obviously signifies that the pressure diaphragm which operates this arm is being subjected to a definite barometric pressure. It is necessary only to provide means for identifying the particular conducting strip being contacted to secure an absolute pressure scale. This is accomplished in simple fashion by means of index marks corresponding to every fifth conducting segment. When the pressure arm contacts a given index segment, a selected fixed resistor is switched into the grid circuit of the special audio oscillator, thereby producing a predetermined modulation frequency which is characteristic of that particular index segment. Experience has shown that a combination of two such identifying frequencies together with varying widths of the index contacts is sufficient for positive identification of the portion of the pressure scale involved. Having established identification of the index contacts, contact of the pressure arm with any conducting strip lying intermediate to the index contacts may now be identified by the sequence of its occurrence with relation to the index contacts preceding and following it. It is merely necessary to indicate that a contact has occurred; for example, by causing it to produce a change in frequency of the audio oscillator. The magnitude of the frequency change has no significance in identifying the intermediate contacts.

The method outlined for securing a positive and absolute pressure scale affords the important advantage of freeing the intermediate contacts for use in switching between temperature and humidity readings indicated on a frequency basis. The fixed resistor R the special hair-controlled resistor H, and the variable resistor formed by the temperature capillary tube T are connected in series in the grid circuit of the audio oscillator as shown in Fig. 4. One set of index contacts of the switching element (numbers 11, 26, 41, etc.) is connected to this series circuit at a; the second set of index contacts (numbers 1, 6, 16, 21, etc.) is connected to the series circuit at point b; and the intermediate conducting strips of the switching element are connected to the resistor circuit at point c. The latter point is the continuously variable contact point formed by rolling of the cam a against the cam resistor f under the action of the hair hygrometer. (See Fig. 2.) The pressure arm P, which moves over the switching element, is electrically connected to ground as is also the lower end of resistor T.

It will be seen that so long as the pressure arm rests on one of the insulating strips of the switching element, the series circuit formed by R, T, and H is undisturbed. Since R is fixed and the full value of H is in the circuit, the frequency of the audio oscillator is controlled by the value of the resistor T only and hence by the temperature. Assume now that the pressure arm contacts one of the intermediate conducting strips. The contact c is thereby connected to ground shorting out a portion of the resistor H (c to b) together with the variable resistor T. The value of resistance remaining in circuit consists of R and a variable portion of H depending upon the position of point c and hence on the value of the relative humidity. The frequency of the audio oscillator is now dependent on the relative humidity. When the pressure arm contacts one of the index segments, it connects either the point a or the point b to ground shorting out H and T together or T alone. In the former

FIG. 5. Ground station receiving and recording equipment.

case, the frequency of the audio oscillator is determined by the resistor R and in the latter case by the resistor R in series with the full value of the resistor H. Hence two fixed identifying frequencies are produced corresponding to the two sets of index contacts. If desired, the identifying frequencies may be made to coincide exactly with the frequencies corresponding to 100 percent and 0 percent relative humidity by suitably arranging the hair element drive of the resistor H to provide for full travel of the contact point c.

The complete operation of the pressure-switching unit now becomes apparent. The pressure arm, moving continuously in one direction as the balloon ascends, switches the frequency of the audio oscillator to correspond alternately to the values of the temperature and of the humidity encountered. The alternate changeovers from one set of frequencies to the other indicate that the pressure arm is just reaching or is just leaving one of the intermediate contacts and has attained definite deflection positions, thereby indicating corresponding values of barometric pressure. When the pressure arm reaches successive fifth conducting segments, the frequency of the audio oscillator attains predetermined fixed values which positively identify these contacts so that they may serve as index marks for the absolute pressure scale. The two identifying frequencies used serve an additional purpose in that they provide periodic checks during the progress of a flight on the degree of frequency stability of the audio oscillator. If any accidental variation should occur, for example, due to varying battery conditions, the recorded value of temperature may be corrected for the indicated variations. Corrections to the humidity readings need not be applied even in such event, as will appear from a study of the type of record obtained at the ground receiving station.

GROUND STATION RECEIVING EQUIPMENT

At the ground station, a graphical audio-frequency recorder is employed in the output of the radio receiving set. An automatic record is obtained on a chart. On this record, the data are directly plotted in the form generally desired by meteorologists; *i.e.*, temperature and humidity as abscissas against pressure as ordinates. A photograph of the ground station receiving and recording equipment used with this system is shown in Fig. 5. The super-regenerative receiving set (at left) feeds an electronic-frequency meter (at the center)

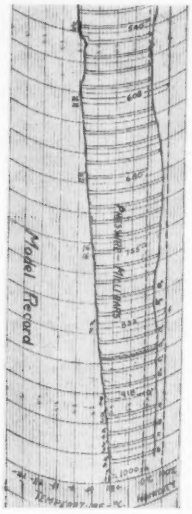

FIG. 6. Model record showing how upper-air pressure, temperature, and humidity are indicated at the ground station.

through a suitable amplifier and electrical filter unit. The electronic-frequency meter operates to deliver a direct current to its indicating meter ranging from 0 to 500 microamperes as the frequency varies from 0 to 200 cycles per second. For operating the recording milliammeter (at the right) a current of 5 milliamperes is required for full scale deflection. The amplifier between the frequency meter and the recorder provides the necessary tenfold amplification. The complete setup is essentially a graphical audio-frequency recorder which converts the audio-frequency notes received in the radio receiver output into a record of the desired form.

Automatic operation is afforded by the receiving setup shown. In a large number of flight tests, no necessity for retuning the radio receiver once the balloon transmitter leaves the ground has been experienced. Two separate automatic volume control features take care of the large variation in received voltage as the distance of the balloon transmitter from the receiving station increases. The first is inherent in the operation of the super-regenerative detector while the second is provided by the frequency meter which operates accurately for a range of input voltages of from 2 to 150 volts.

The type of record obtained is indicated in Fig. 6. Since points along the scale of abscissas on the chart represent specific values of audio frequency (from 0 to 200 cycles per second), they may be interpreted directly in terms of the corresponding values of temperature and humidity. This is facilitated by marking the temperature and humidity scales on the chart; corresponding to the particular values of R, H, and T used. The start of the run is at the bottom of the chart. For the record shown, the pressure arm reached the

first index contact (corresponding to a barometric pressure of 1000 millibars) at 1 and passed over this contact at 1′. During that interval the frequency indicated (*a*) was that of the first identifying frequency. As the pressure arm passed on to an insulating strip, the temperature resistor took over the control of the audio oscillator producing the frequency trace from 1′ to 2. The insulating strips are arranged to have a width about five times that of the unit conducting strips, so that the temperature indication is obtained during five-sixths of the time. At 2, the pressure arm reached the first intermediate contact (corresponding to a barometric pressure of 984 millibars), at which point the humidity resistor took control of the audio oscillator producing the frequency indication *b*. The changeovers from temperature to humidity frequency indications occurred each time the pressure arm passed over an intermediate contact and were thus repeated in groups of four between successive index contacts. (See *b*, *c*, *d*, *e*, etc.) In between these readings, the pressure arm was passing over the insulating strips so that frequencies corresponding to the temperature were recorded. (See traces from 2′ to 3, 3′ to 4, 4′ to 5, 5′ to 6, etc.) After each group of humidity readings, the index contacts provided one of two identifying frequencies, depending on which index contact was being passed over by the pressure arm. It will be seen that the first identifying frequency was repeated twice (contacts 1, 6, 16, 21, etc.) and then the second identifying frequency was used (contacts 11, 26, 41, etc.). Also a double width of contact was used for the second set of index contacts. Any one of a large number of combinations may be used for providing positive identification. Corresponding to each humidity reading and to each indication of an identifying frequency, a definite value of barometric pressure obtained. For convenience, only the pressure values corresponding to the index contacts are shown on the record.

Summarizing, the record represents an automatic plot of temperature and humidity as abscissas against pressure as ordinates. The temperature graph is the line drawn in to connect the successive temperature indications. Similarly, the humidity graph is the line drawn in to connect the successive humidity indications. The two lines connecting the recorded values of the two identifying frequencies may be made to represent the 0 and 100 percent values of relative humidity. Any departure of these from straight lines indicates that a correction should be applied to the temperature readings, the degree of departure fixing the magnitude of the correction on a proportional basis. No correction need be applied to the humidity readings, since these may be read off on a corrected basis in relation to the two lines. The pressure values are inserted on the chart after first identifying the different index contacts (and then the intermediate contacts). The corresponding values as determined from previous calibration of the switching unit are marked on the lower horizontal traces of the contact readings. These values are on an absolute basis and depend in accuracy only on the design of the pressure diaphragm and linkage and on the accuracy of calibration.

The Temperature Unit

An experimental model of the capillary tube of sulphuric acid solution used for securing temperature indication over the required temperature range was shown at *T* in Fig. 3. Aside from the advantage of eliminating mechanical parts, the capillary tube offers several other advantages over the bi-metallic thermometer. One advantage is its property of responding very rapidly to temperature changes. A simple test will indicate the rate of response obtained. A sample tube was taken out of a temperature chamber of −50° C. and exposed to still air at +20° C. In 10 seconds the electrical resistance of the tube changed from its value at −50° C. to a value corresponding to +10° C., and in 5 more seconds it reached a value corresponding to +18° C. The value of the high rate of response of the temperature device in the method of pressure-switching has already been indicated. Another advantage of the capillary temperature device lies in its lack of metallic connection to the body of the meteorograph; only two small connecting leads are required. This simplifies considerably the problem of isolating the temperature unit to the temperature of the surrounding air. The length and small diameter of the capillary tube contribute to such isolation.

Calibration and Performance

An advantage of the radio meteorograph described lies in the ease of calibration of its component units. Each of the three units may be calibrated independently.

To calibrate the pressure unit, a resistor of convenient value is substituted in the meteorograph for the capillary tube. The meteorograph unit is placed in a pressure chamber and an ohmmeter is connected between the upper end of the humidity resistor and ground. (See Fig. 4.) As the pressure chamber is evacuated, the ohmmeter will indicate the switching operations performed by the pressure arm. As the pressure arm passes over the index contacts, the ohmmeter will read either zero resistance corresponding to one set of index contacts or the total value of the humidity resistor corresponding to the second set. For intermediate contacts, the ohmmeter will read the value of a portion of the humidity resistor depending on the humidity conditions in the pressure chamber. Between contacts the ohmmeter will show the value of the resistor substituted for the temperature device. For each contact, the value of the pressure is recorded corresponding to the instant of making the contact.

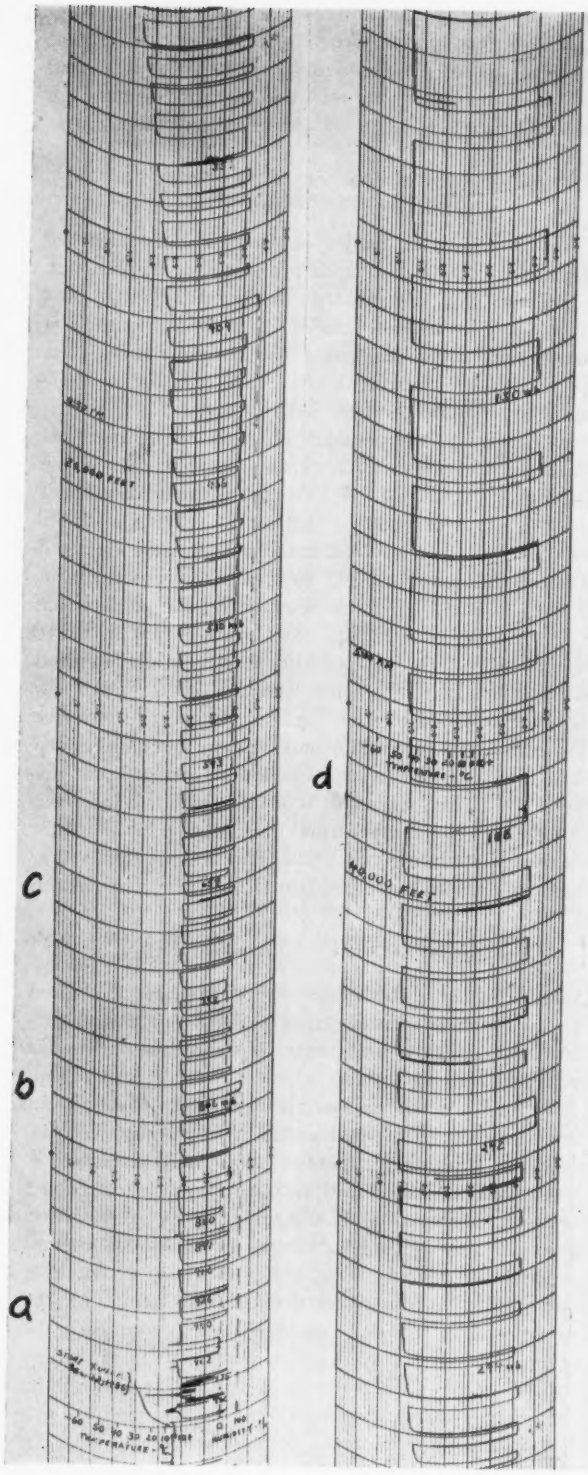

FIG. 7. Sample ascension record.

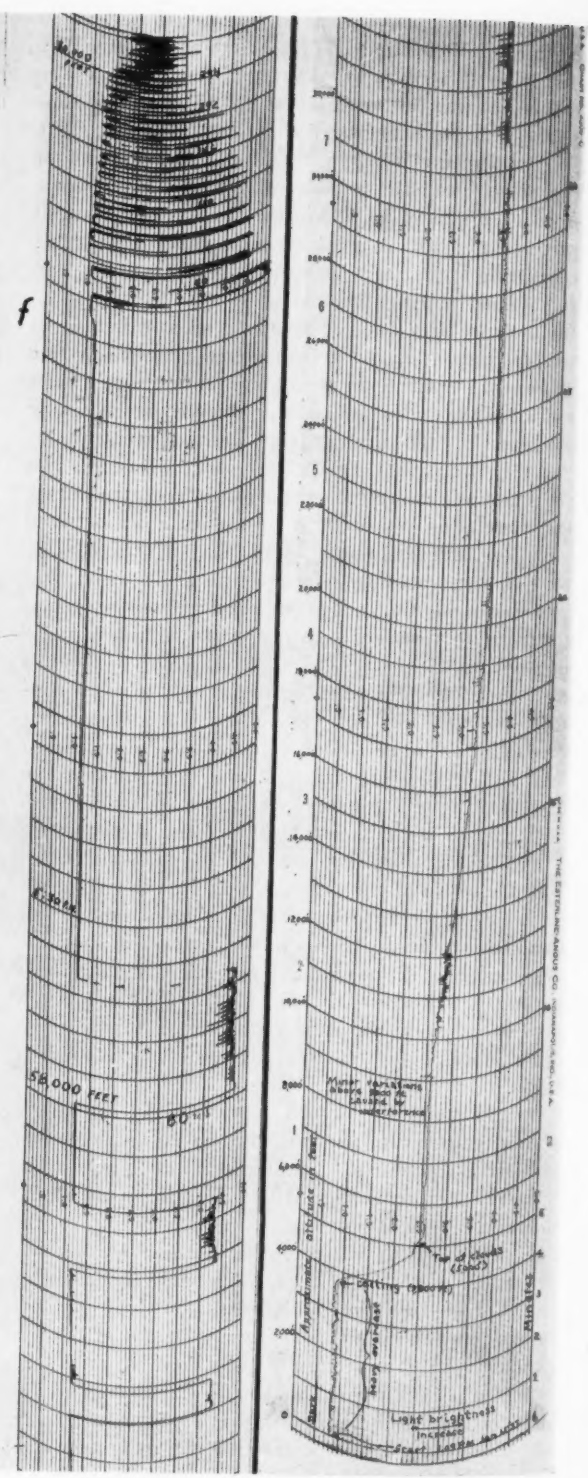

FIG. 9. Radiograph of light brightness giving ceiling and height to top of clouds. Approximate height determined by rate of ascent of balloon.

A complete calibration of the pressure unit can be carried out in ten to fifteen minutes. In the calibration of a number of such units, the indicated accuracy appears to be better than one millibar.

Calibration of the humidity device is accomplished by placing the meteorograph in a humidity chamber and measuring the resistance between points *a* and *c* (Fig. 4) corresponding to varying values of relative humidity. These resistance readings may be readily converted to the corresponding values of frequency generated by the audio oscillator from the reciprocal resistance relation of the oscillator.

Calibration of the temperature device consists of placing it in a temperature chamber and connecting it electrically in the grid circuit of a test audio oscillator. Its resistance at a given temperature may be measured by measuring the audio frequency generated and substituting for it a standard variable resistor which is adjusted to produce the same generated frequency. The same test provides data for plotting the audio frequency as a function of temperature.

It is possible to make the pressure scale approximately linear with either pressure or altitude by controlling the pressure arm linkage. The linear pressure scale has been adopted in our design since it affords a greater number of readings at the lower altitudes for a given number of contact segments in the pressure-switching element. In one design of the switching element, 75 contact segments are used. This provides pressure (and also humidity) readings at increments in the altitude of less than 500 feet during the first 15,000 feet of an ascent. These increments may be further reduced, if desired, by increasing the number of segments in the switching element. In any case the temperature readings are continuous between contacts, occurring for five-sixths of the time. Thus, for the design described, temperature indication is obtained continuously during 415 feet of each 500 feet increment in altitude up to 15,000 feet.

Sample Ascension Record

A number of ascensions were made using the pressure-switching radio meteorograph described. These have shown the system to be practicable and have provided gratifying records. While further work on the system is expected to modify the appearance of the records through the use of a recorder having a greater chart width and slower paper speed, nevertheless a sample of the records obtained to date is considered of interest. Fig. 7 shows such a record. Because of its length, the chart was photographed in three sections.

Referring to Fig. 7, the left-hand strip (at the bottom) corresponds to the beginning of the ascension and the right-hand strip (at the top) to the end. The temperature of the air at the ground level was +4° C. and the relative humidity at the ground was 40 percent. The first pressure reading (corresponding to an intermediate contact and hence giving also a humidity reading) was at a pressure level of 1011 millibars and occurred at a height above ground of 275 feet. The first index contact corresponded to a pressure level of 962 millibars, the second to a pressure of 880 millibars, the third to a pressure of 806 millibars etc. For convenience, the pressures corresponding to the intermediate (humidity) contacts are shown only for the first two groups. It will be observed that the index contacts are defined not only by using the lower-frequency value in successive groups of two but also by a triple contact thickness of one of the lower-frequency indexes and a double contact thickness of the higher-frequency indexes. The variation of temperature as a function of barometric pressure is shown by the practically continuous line formed by the frequency traces at the left of the three strips. The variation of humidity with barometric pressure is shown by the line connecting the frequency traces occurring during the intermediate contacts. This graph is bounded by the two lines connecting the lower and upper index frequencies and corresponding respectively to 0 and 100 percent relative humidity. Temperature inversions occurred at *a*, *b*, *c*, and *d*.

The final pressure indication (80 millibars), corresponding to the 75th conducting strip of the pressure-switching element, occurred at an altitude of approximately 58,000 feet. As the balloon ascended above this altitude, the pressure arm moved over an insulating strip provided at the end of the switching element. A continuous record of temperature was therefore obtained above this level. At point *f*, the balloon burst and the instrument began falling. This is evident from the sudden decrease in the indicated temperature apparently caused by the added ventilation of the radiation shields due to the high rate of descent. The movement of the pressure arm then reversed and made contact with the conducting strips of the switching element in reverse direction from that during the ascent. The balloon was estimated to be about 150 miles from the receiving station when it burst. From computations based on the net change in altitude between any two contacts divided by the time interval between the occurrence of the contacts, the rate of descent averaged 5000 feet per minute. Even at this rapid rate, the temperature indications obtained were within a few degrees of the corresponding indications recorded during the ascent.

Computation of the balloon rate of ascent (on the same basis as just indicated for rate of descent) has enabled the checking of the accuracy of pressure indication under actual conditions. Calm weather was chosen for this purpose so that the balloon rate of ascent could be assumed constant. Under these conditions, a series of ascension tests showed maximum deviations from a constant ascension rate such as would be produced by an error in the pressure indications of one millibar.

Improved Humidity Device

The hair hygrometer, because of its inherent lag in response, limits the use of a high rate of balloon ascent otherwise possible with a radio meteorograph employing this method. Much work was devoted to the development of a humidity device comprising a resistor the electrical resistance of which would vary inherently with humidity. In this way it was hoped to secure greater rate of response to humidity changes. In order that such a device repeat accurately it must not be changed physically by low pressure, temperature, or by the absorption or adsorption of water vapor. The experiments included the study of the possible adaptation of hygroscopic salts and of acids to this purpose. Temperature errors, crystallization of the salts, and evaporation of the acids were some of the inherent difficulties encountered. An arrangement was finally devised which is free from these difficulties. (See Fig. 8.) The device consists of a soda-lime glass tube with etched surface and wound with a dual winding of bare copper wire. The turns of the two windings are spaced about 1 millimeter apart. The adsorption of water vapor by the etched glass surface causes a marked change in the electrical resistance between the two windings. Measurements in a controlled chamber and under actual conditions out-of-doors indicate that the change in resistance is proportional to the relative humidity of the ambient air and is practically free from temperature effects. The device responds rapidly to humidity variations. At room temperature, with a circulation of air equivalent to that on the balloon, full response to a relative humidity change of from 100 to 20 percent occurs in about one minute. Nearly the same rate of response may be obtained under conditions of abrupt temperature changes by making the walls of the tube as thin as possible.

It is necessary to modify the switching circuit arrangement of Fig. 4 when using the inherently varying humidity resistor. A simple light-weight relay of minute current consumption is closed by contact of the pressure arm with the intermediate conducting strips of the switching element. When the pressure arm is on an insulating segment, the back contact of the relay connects the temperature resistor into the audio-oscillator circuit, while when the pressure arm is on an intermediate conducting segment, the front contact of the relay connects the humidity resistor into the circuit. With this arrangement, the full recorder scale is used for both the temperature and the humidity indications.

It may be of interest at this point to summarize the advantages of the pressure-switching method incorporating a humidity device having rapid response. Since the other meteorological elements employed also have rapid response and there is no limitation to the speed of recording, the rate of ascent employed may

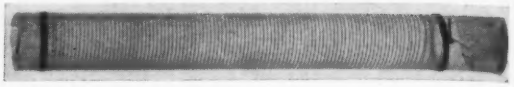

Fig. 8. Humidity device which varies inherently in electrical resistance as a function of absolute humidity.

be the highest practical value. Advantages of this are: (1) less time taken for a record; (2) since the balloon will not drift so far, data may be secured during the descent as well as during the ascent; (3) the possibility of recovery of the instrument, particularly in near-coastal regions, becomes greater; (4) the battery requirements are reduced because of the shorter time of flight; and (5) better ventilation of the radiation shield is provided.

Simplified Equipment for Determining Height to Top of Clouds

For aeronautical purposes, it is frequently desired to measure the height to the top of existing clouds where clear visibility obtains. This may be determined by connecting a photoelectric cell in the grid circuit of the special audio oscillator so that its change in electrical resistance with light intensity will vary the modulation frequency of the emitted signal. The balloon rate of ascent may be relied upon for estimating the altitude, since a close determination of altitude is not required in this application. The equipment required is then quite simple. A record obtained with this type of equipment is shown in Fig. 9. Heavy overcast with intermittent rains occurred on the day of the test, Jan. 15, 1937. The window of the photoelectric cell was pointed downward to eliminate the effect of direct sunlight upon emergence from the clouds. Referring to the record, the abscissas represent light brightness, the reference line marked DARK corresponding to the complete absence of light. The light brightness was quite low up to the ceiling (approximately 3800 feet). From that point, it increased rapidly as the balloon ascended through the cloud layer. At about 5200 feet, the balloon emerged on top of the cloud. Above this altitude, the light brightness gradually increased reaching approximately constant value at about 20,000 feet. Haze apparently existed between about 10,000 and 20,000 feet.

Acknowledgment

The writers wish to express their appreciation to L. L. Hughes of the Radio Section for his skillful construction and contributions to the mechanical design of numerous experimental models, to G. W. Vinal and D. N. Craig of the Battery Section and E. O. Sperling of the Glass Blowing Shop for suggestions on the design of the temperature device adopted, to J. P. Schrodt and C. L. Snyder of the Battery Section for assistance in determining battery requirements, to W. G. Brombacher of the Aeronautic Instruments Section for advice and data on meteorological instruments and calibration equipment and procedure, and, to M. Shepherd, J. R. Branham, and C. P. Saylor of the Chemistry Division, for suggestions in the study of salt and acid hygrometers. Special acknowledgment is due the Julien P. Friez Co. for cooperation in this program.

On the Strength of Columns that Fail by Twisting

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Presented at the Structural Problems in Aircraft Design Session, Fifth Annual Meeting, I. Ae. S. January 27, 1937

SUMMARY

A FEW of the basic considerations in twisting failure of columns are presented and illustrated without recourse to detailed mathematics. It is stated that the Wagner theory for twisting failure applies when the cross sections rotate about any axis parallel to the column. The axis of rotation will then take such a position consistent with the conditions of support as will cause the critical stress to be a minimum. This general case of twisting failure is designated "primary failure."

The theory is illustrated with charts giving the strength of an angle- and of a channel-section column for different locations of the axis of rotation. When the column is loaded above the proportional limit, effective moduli must be introduced into the equation for the critical stress.

For a free column, the critical stress is given by the sum of two terms: a bending term and a twisting term. When the bending term constitutes an appreciable part of the critical stress, the principal action of twisting failure is very similar to that of bending failure in an ordinary column. In such cases the allowable stress is very near, if not equal to the critical stress at which twisting begins.

INTRODUCTION

For several years the National Advisory Committee for Aeronautics has been studying the strength of columns formed of thin metal. The latest Committee report on this subject[1] deals with twisting failure both when the column is free and when it is attached to the skin of a stressed-skin structure. The purpose of the present paper is briefly to summarize a few of the basic considerations in twisting failure of columns and to illustrate them without recourse to detailed mathematics.

Acknowledgment is here made of the work of Claude M. Fligg and Bernard Rubinstein, who with the author are making an extended study of the strength of thin-metal columns used in aircraft structures.

Columns that have a low torsional rigidity may fail by twisting provided that the strength for some other type of failure is not less than the strength for twisting failure. In N.A.C.A. Report 582 all types of column failure are classed under two headings: (a) primary failure, and (b) secondary or local failure. Primary failure is defined as any type of column failure in which the cross sections are translated, rotated, or both translated and rotated but not distorted in their own planes (Fig. 1). Secondary or local failure is defined as any type of column failure in which the cross sections are distorted in their own planes but not translated or rotated (Fig. 2).

FIG. 1. Primary column failure.

FIG. 2. Secondary or local failure.

The present theory for bending failure developed by Euler, Considere, Engesser, and von Kármán,[2,3,4] as well as the recent theory for twisting failure developed by Wagner,[5,6] are both special cases of a general theory for primary failure.[1] In the theory for primary failure every combination of translation and rotation of the column cross section is expressed as a rotation about some axis hereinafter called the "axis of rotation" (Fig. 3).

For a free column, the axis of rotation will take such a location as will cause the critical stress to be a minimum. When the column is attached to the skin of a stressed-skin structure, the stiffness of the skin in its own plane and the anchorage of the skin at the sides of

[1] Eugene E. Lundquist and Claude M. Fligg, *A Theory for Primary Failure of Straight Centrally Loaded Columns*, N.A.C.A. Tech. Rept. 582, 1936.

[2] S. Timoshenko, *Strength of Materials*, Part II, D. Van Nostrand Co., Inc., 1930, p. 572, art. 37.

[3] William R. Osgood, *Column Curves and Stress-Strain Diagrams*, Research Paper No. 492, Nat. Bur. Standards, 1932.

[4] William R. Osgood, *The Double-Modulus Theory of Column Action*, Civil Engineering, March, 1935, pp. 173–175.

[5] Herbert Wagner, *Torsion and Buckling of Open Sections*, N.A.C.A. Tech. Memo. 807, 1936.

[6] H. Wagner and W. Pretschner, *Torsion and Buckling of Open Sections*, N.A.C.A. Tech. Memo. 784, 1936.

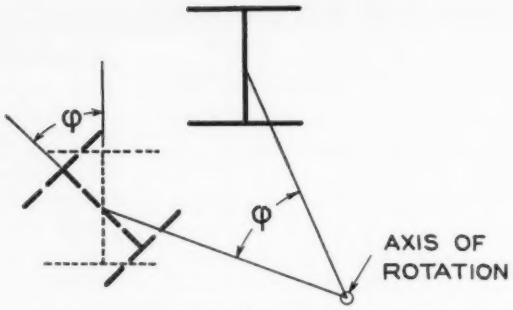

FIG. 3. Combination of translation and rotation.

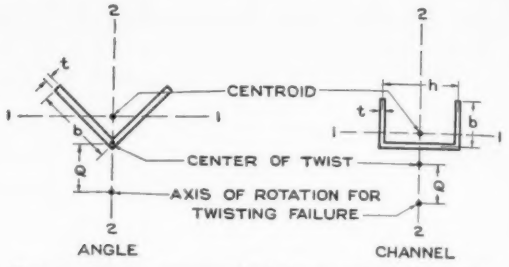

FIG. 4. Sections symmetrical about one principal axis.

the panel force the axis of rotation to lie near the plane of the skin, if not actually in the plane of the skin. The axis of rotation will then take such a location in or near the plane of the skin as will cause the critical stress to be a minimum. In general, then, the axis of rotation will take such a position consistent with the conditions of support as will cause the critical stress to be a minimum.

EQUATION FOR CRITICAL STRESS IN PRIMARY FAILURE

The critical compressive stress for primary failure of a column that is both straight and centrally loaded is (Eq. 1 of N.A.C.A. Report 582)

$$f_{crit} = \frac{GJ}{I_p} + \frac{C_{BT}\,\pi^2 E}{I_p \quad L_0^2} \tag{1}$$

where E is the tension-compression modulus of elasticity,

$G = \dfrac{E}{2(1+\mu)}$ shear modulus of elasticity,

μ, Poisson's ratio for the material,

I_p, polar moment of inertia of the cross section about the axis of rotation,

L_0, effective length of column,

J, torsion constant for the section. The product GJ in torsion problems is analogous to the product EI in bending problems.[7]

C_{BT}, torsion-bending constant, dependent upon the location of the axis of rotation and the dimensions of the cross section.[1,5,6,8]

It should be mentioned here that the derivation of Eq. (1) is due to Herbert Wagner of Germany. If Eq. (9) of N.A.C.A. Technical Memorandum 807 is written with American notation and then both sides of the equation divided by the cross-sectional area A, Eq. (1) of this paper is obtained. In his derivation Wagner assumed that, on buckling, the cross sections of the column rotate about an axis parallel to the column and passing through the center of twist for the section. However, the equation is also valid when the cross sections rotate about *any axis* parallel to the column.[1]

In Eq. (1) the term GJ/I_p is that part of the critical compressive stress caused by the resistance of the column to pure twisting. (See Pugsley[9] Eq. (4a).) The term $C_{BT}\,\pi^2 E/I_p\,L_0^2$, is that part of the critical compressive stress caused by the resistance of the column to bending. In the derivation of Eq. (1) the angular displacement of the cross sections about the axis of rotation was found to vary as a half sine wave along the length of the column in the same way that the lateral displacements in an Euler column vary as a half sine wave along the length. The term C_{BT}/I_p is, therefore, analogous to I/A in the Euler column formula

$$f_{crit} = \frac{I \quad \pi^2 E}{A \quad L_0^2} \tag{2}$$

where I is the moment of inertia about a centroidal axis.

When the axis of rotation is at infinity, both C_{BT} and I_p become infinite. In this case, the term GJ/I_p is zero and $C_{BT}/I_p = I/A$.[1] Thus, when the axis of rotation is at infinity, there is no twisting and Eq. (1) reduces to the Euler formula of Eq. (2). For all locations of the axis of rotation other than infinity, the critical stress is given by the sum of two terms: a twisting term, GJ/I_p, and a bending term, $C_{BT}\,\pi^2 E/I_p\,L_0^2$.

SEVERAL APPLICATIONS OF EQ. (1)

In order to illustrate some of the results that are obtained when Eq. (1) is applied to columns, two familiar cross sections, each symmetrical about one principal axis, will be considered (Fig. 4). Timoshenko[10] discusses the location of the point designated "center of twist" for both the angle and channel cross sections. For each of these cross sections the center of twist lies on the axis of symmetry, principal axis 2–2 in Fig. 4.

[7] George W. Trayer and H. W. March, *The Torsion of Members Having Sections Common in Aircraft Construction*, N.A.C.A. Tech. Rept. 334, 1930.

[8] Warren S. Parr and Wallace M. Beakley, *An Investigation of Duralumin Channel Section Struts under Compression*, J. Aero. Sci., Vol. 3, No. 1, Sept., 1935, pp. 21–25.

[9] A. G. Pugsley, *The Torsional Instability of Struts*, Aircraft Engineering, Sept., 1932.

[10] S. Timoshenko, *Strength of Materials*, Part I, D. Van Nostrand Co., Inc., 1930, p. 194, art. 41.

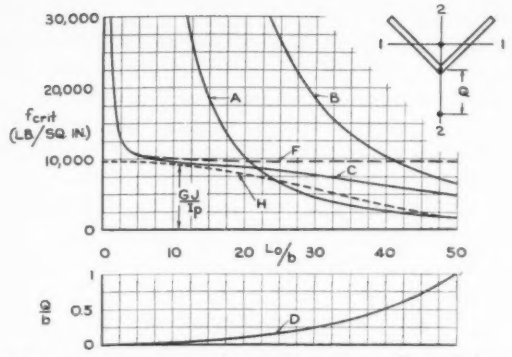

FIG. 5. Column curves for angle section. (b = 2 in.; t = 0.100 in.; E = 10^7 lbs. per sq. in.; G = 0.385 E.)

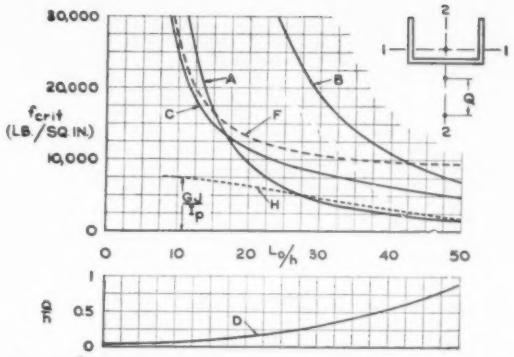

FIG. 6. Column curves for channel section. (b/h = 0.6; h/t = 20; E = 10^7 lbs. per sq. in.; G = 0.385 E.)

Angle Section.

Fig. 5 contains column curves for an angle section computed from Eq. (1) for different locations of the axis of rotation. For curves A and B, the axis of rotation is at infinity on axes 1–1 and 2–2, respectively. These curves are the Euler curves for bending about the principal axes of the section. For twisting failure the axis of rotation will take such a location Q along line 2–2 as will cause the critical stress to be a minimum. This value of Q varies with the length as shown by curve D. The critical stress for twisting failure is given by curve C. As the length approaches infinity, Q approaches infinity and curve C approaches curve B. Thus, curve C might be thought of as the Euler curve for bending about principal axis 2–2, with proper consideration given to the effect of twisting caused by the displacement of the center of twist from the centroid. Because both curves A and C are always below curve B, it is concluded that failure can never occur by bending about axis 2–2. Instead, failure will always occur by bending about axis 1–1 (curve A, Fig. 5) or by twisting about some point on axis 2–2 (curve C, Fig. 5), depending upon which gives the lower critical stress for the length considered.

To the left of the intersection of curves A and C (Fig. 5) the critical stress given by curve C is the lower. This portion of curve C, the only portion of concern to the designer, is closely approximated by curve F, which is drawn for the axis of rotation located at the center of twist (Q = 0).

Channel Section.

Fig. 6 is similar in all respects to Fig. 5 except that it is drawn for a channel section. Because the angle and channel sections are both symmetrical about principal axis 2–2, the preceding discussion of the angle section applies to the channel section.

In previous publications[5,6,8] it has been assumed that for twisting failure the axis of rotation is located at the center of twist (sometimes referred to as the "shear center"). From the fact that the axis of rotation will take such a location as will cause the critical stress to be a minimum, it can be proved that, for a column of any cross-sectional shape, the axis of rotation will never be closer to the center of twist than the location that causes C_{BT}/I_p to be a minimum. For the angle section, this location of the axis of rotation is very near the center of twist, Q = 0, but, for the channel section, it is somewhat removed from the center of twist. (Compare curves D in Figs. 5 and 6.)

For the channel section of Fig. 6 the smallest value of Q that causes C_{BT}/I_p to be a minimum is 0.044 h. (See curve D.) Thus, for the channel section, a better approximation of the portion of curve C lying to the left of its intersection with curve A is obtained when the axis of rotation is placed at the location that causes C_{BT}/I_p to be a minimum rather than at the center of twist.

Effective Values of E and G at High Stresses

In ordinary columns failure occurs by bending. For such columns, the critical stresses depart from the theoretical values given by the Euler formula at short lengths. Consequently, an empirical straight line or parabolic curve is frequently drawn on the column chart to give the critical stress in this range. Likewise, for the general case of primary failure there will be a similar departure of the critical stress from the theoretical values given by Eq. (1) and corresponding curves must be found to give the strength for short lengths.

The reason for the departure of the experimental values of the critical stress from the theoretical values at short lengths is caused by the reduced slope of the stress-strain curve at the high stresses associated with short lengths. In the ordinary column this effect is provided for by the introduction of an effective modulus $\mathbf{E}$ for E in Eq. (2). (See Timoshenko[2] and Osgood[3,4].) Likewise, for primary failure at high stresses, effective moduli $\mathbf{E}$ and $\mathbf{G}$ are substituted for E and G in Eq. (1).

It is beyond the scope of this short paper to discuss the evaluation of $\mathbf{E}$ and $\mathbf{G}$ as completely as would be desirable. It will suffice to state, however, that the value of $\mathbf{E}$ is dependent upon the shape of the column

FIG. 7.

cross section and upon the location of the axis of rotation, whereas **G** is probably not affected by these factors to any appreciable extent, if at all.

In Report 582[1] it is shown how values of **E** and **G** may be obtained from the accepted column curve for the material. (The effective values of E and G designated by **E** and **G** in this paper, are designated by $\overline{E}$ and $\overline{G}$ in Report 582.) The values of **E** so obtained may then be corrected for the effects of cross-sectional shape and location of the axis of rotation, if desired. In many cases, however, these corrections will be small and can be neglected.

SKIN-STIFFENER COMBINATIONS

When a column is attached to the skin of a stressed-skin structure and failure occurs by twisting, the skin will resist twisting of the column and another term must be added to the right side of Eq. (1). This additional term is discussed in Report 582[1] where a method is given for constructing the column curve for a skin-stiffener combination.

ALLOWABLE STRESS FOR DESIGN

In the design of structures involving columns that may fail by twisting, one of the questions to be answered is: What should the allowable stress be? In a short paper such as this one, it is impossible to discuss the subject as fully as might be desired. A few simple considerations, however, will aid materially in providing a practical answer to this question.

In the design of airplane structures the practice is to multiply the probable applied load by a factor greater than unity to obtain the "design load." The structure is then proportioned so that its "ultimate strength" is equal to, or in excess of, the design load, provided that either deflection or permanent set associated with ultimate strength is not a factor to be considered.

In an ordinary column, any attempt to apply load in excess of the critical load at which buckling begins results in either large deflection or permanent set, both of which are objectionable. When the column is long the deflection is large for even a small increment of load in excess of the critical load. When the column is short, the stress is high and a small deflection will overload one side of the column, causing either the material to yield or a thin part to fail locally. Thus, in the design of ordinary columns for aircraft, it is common practice to assume that the allowable stress is the critical stress at which buckling begins or some lower value dependent upon the initial eccentricity and crookedness of the column.

In the general case of primary failure, twisting usually occurs only when the column is short. (See Figs. 5 and 6.) Then, if the bending term in Eq. (1) constitutes an appreciable part of the critical stress, a small amount of twist will overload one or more parts of the column, causing either the material to yield or a thin part to fail locally. Thus, even though the column twists, the action is very similar to that in an ordinary column when bending occurs, as might be inferred from the similarity of the bending term in Eq. (1) and the Euler formula of Eq. (2).

In Figs. 5 and 6, curve H is drawn to show how much of the critical stress for twisting failure is contributed by the twisting term GJ/I_p. The difference between the ordinates of curves C and H is the amount contributed by the bending term

$$\frac{C_{BT}}{I_p}\frac{\pi^2 E}{L_0^2}$$

Where curve C is below curve A for the angle section, the bending term accounts for only a small part of the critical stress, except at very short lengths. This small value of the bending term is explained as follows: When the axis of rotation is at the corner of the angle, each leg bends normal to its own plane in the manner of a plate simply supported along one edge. Then, because the legs are thin, the bending term is small for all but very short lengths.

For the channel section, where curve C is below curve A, the bending term in Eq. (1) accounts for a very large part of the critical stress. This large value of the bending term is explained as follows: A channel is formed of three plates (a back and two legs), which makes it impossible to find a location for the axis of rotation that does not cause one or more of the plates to bend in its own plane when twisting occurs. Then, because the width of the back and legs is several times their thickness, the bending term for the channel section is very large compared with the bending term for the angle section.

In Fig. 7 are shown some of the sections for which the bending term will predominate. When columns having these cross sections fail by twisting, the principal action is very similar to that of bending and the allowable stress for aircraft design is very near, if not equal to, the critical stress given by Eq. (1).

CONCLUSIONS

(1) All types of column failure may be classed under two headings: (a) primary failure, and (b) secondary or local failure.

(2) The critical stress for primary failure, which includes twisting failure, is given by Eq (1).

(3) For primary failure, the axis of rotation will take such a position consistent with the conditions of support as will cause the critical stress to be a minimum.

(4) When the axis of rotation is at infinity on one of the principal axes of the section, failure occurs by bending and Eq. (1) reduces to the Euler formula.

(5) At high stresses effective moduli **E** and **G** must be substituted for E and G in Eq. (1).

(6) When a column is attached to the skin of a stressed-skin structure and failure occurs by twisting, the skin will resist twisting of the column and another term must be added to the right side of Eq. (1).

(7) When the bending term in Eq. (1) contributes an appreciable portion to the critical stress, the allowable stress for design is very near, if not equal to, the critical stress at which twisting begins.

Book Reviews

The Airplane and Its Engine, by C. H. CHATFIELD, C. FAYETTE TAYLOR, AND SHATSWELL OBER; McGraw-Hill Book Company, 1936; 401 pages, ill., $3.00.

In bringing out the third edition of this book the authors state that they "have tried wherever possible to clarify the text, to amplify the explanations of fundamental principles, and to make the additions and changes needed to take account of the progress in aeronautics during the four years since the second edition was written."

In this book of 400 pages they have made available to the student an unusual amount of information, not too technical in nature but of a type which can be easily absorbed to obtain a general knowledge of the airplane and engine. The book is particularly well illustrated with both drawings and photographs of some of the latest equipment. The information appears to be more up to date than is usually found in text books, and also is quite accurate although there are some opinions expressed with which all engineers would not agree.

On page 220, the statement is made that "For very large engines, where design limitations of air cooling become serious, water cooling seems to be the logical choice." As far as is known, limitations of air cooling have not been reached with powers as high as 135 horsepower per cylinder, which would mean in an engine of 18 cylinders over 2400 horsepower.

On page 134, a statement is made that "fuel consumption increases with altitude." This statement is somewhat misleading and if the qualification had been added that the engine was a sea level engine, the statement would be correct. On a supercharged engine the fuel consumption decreases with altitude up to the critical altitude of the engine because of the decrease in back pressure plus the fact that at sea level the supercharger is using approximately the same power as it is at high altitude.

The book is divided into sixteen chapters covering the essential parts of the airplane—The Wing, Airfoil Modifications and Arrangements, Parasite Drag, and Stability of Control. Chapters on engines include the general principles, operating characteristics, type, details of construction, and complete power plant. The propeller is covered in a separate chapter. There are complete chapters on airplane performance, airplane maneuvers, and the airplane structure; seaplanes, amphibians, and commercial and military airplanes. A complete chapter is also devoted to aircraft instruments and accessories.

In looking through the index to this book one finds almost every detail of the airplane and engine is covered. The book should be very valuable as a means of instruction in schools and colleges. The authors are to be congratulated on the handling of such a voluminous subject in such a clear, concise, and thorough manner.

ARTHUR NUTT
Wright Aeronautical Corporation

1937 Model Aeronautics Yearbook, by FRANK ZAIC; Model Aeronautics Publication, New York, 1937; 160 pages, ill.

Anyone who thinks that the builders of models are not studying the aerodynamics of flight will be surprised to see the graphs, formulae, and diagrams which are now used by the builders of advanced types of models. It is surprising to note that ten different makes of engines are now available for the builders of larger types of models. When records of flights of one hour and fifteen minutes and speeds of 33.25 m.p.h. are attained it must be apparent that more than guesswork is used by the designers. This handbook is written for the expert builder who wishes to keep abreast of the latest work in models and Mr. Zaic is to be commended for the thoroughness with which he has covered the subject.

Ships Aloft, by CLAYTON KNIGHT AND HAROLD PLATT; Harper & Brothers, New York, 1936; 19 pages, $2.50.

What is without doubt the most beautifully prepared book for the younger generation of aviation enthusiasts is "Ships Aloft." It combines the artistry of Clayton Knight with technical accuracy in presenting several of the leading types of American airplanes for making cut-out models. The Douglas Airliner, The China Clipper, The Boeing Bomber, and a Shipboard Fighter are pictured in lithographs on stout paper which may be made into models with little effort. It is books such as this which are doing so much to stimulate and interest the next generation.

Aerodynamic Factors in the Design of Long Range Flying Boats

B. C. BOULTON, *The Glenn L. Martin Company*

Presented at the Long Range Seaplane and Airship Problems Session, Fifth Annual Meeting, I. Ae. S., January 27, 1937

THE PRIMARY AIM, in a flying boat design, after having satisfied the special conditions of a given problem, is to secure the maximum payload for a given range at the highest possible cruising speed. There are two aspects of the problem: flight at economical speed, *i.e.*, at or near $L/D_{max.}$, depending on the specific airplane engine characteristics; or flight at higher speeds, limited by permissible engine power. The solution differs somewhat in the two cases due to the varying relative importance of the induced and the parasite drag.

This paper endeavors to present a study of the various prime factors affecting cruising speed and range: namely, wing span, parasite drag, propeller efficiency, specific fuel consumption, altitude, headwind, and gross weight.

The basic law governing the drag of a wing or of a complete airplane is given by

$$C_D = C_{D_0} + C_{D_i} \qquad (1)$$

where $C_{D_i} = BC_L^2$. The theoretical value of C_{D_i} is $C_L^2/\pi R$. This latter value is not strictly true, since neither the wing profile drag nor the structural parasite items are constant with varying angle of attack. The factor "B" corrects the theoretical to the actual induced drag, making allowance for mutual interference, departures from ideal lift distribution, and for the variation of profile and parasite drags with angle of attack. This expression holds very well within the normal flying range from $C_L = .2$ to 1.0.

Usually C_D is plotted *vs.* C_L giving the familiar polar, Fig. 1. Should C_D be plotted against C_L^2, as in Fig. 2, the graph is a straight line within the limits of C_L noted and the slope of this line is "B." The induced drag correction factor "e" may be defined as $\sqrt{1/\pi RB}$ and the effective span as $e \times S$. This conception of "e" and particularly the method of obtaining it are both simple and important.

Referring to the plot of C_D versus C_L^2, the intercept on the C_D axis for $C_L = 0$, represents the C_{D_0} term in Eq. (1) above, or the combined wing profile and parasite drag.

If A_p = A flat plate area equivalent to C_{D_0}.
C_p = .00327 = Drag coefficient of this area.
W = Gross weight.
V = Velocity of flight.
σ = ρ/ρ_0 = Relative density.

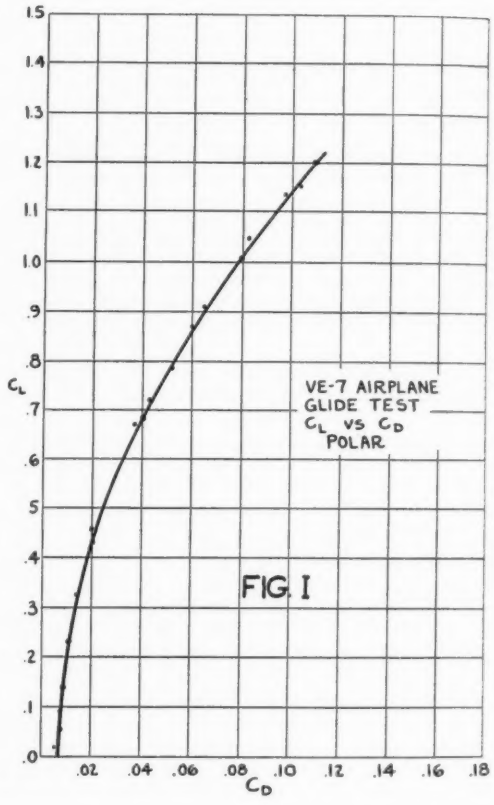

FIG. I

Then $$\text{drag} = C_p A_p \sigma V^2 + 125 \left(\frac{W}{S_e}\right)^2 \times \frac{1}{\sigma V^2} \qquad (2)$$

expressed in engineering units of lbs./sq. ft. and m.p.h. If this equation is differentiated and put equal to zero and solved for V, the speed of minimum drag or maximum L/D,

$$V = 13.95 \left(\frac{W}{S_e}\right)^{1/2} \times \frac{1}{\sigma^{1/2} A_p^{1/4}} \qquad (3)$$

Another interesting relationship that may be determined by substituting V from Eq. (3) in Eq. (2) is that

$$D_{\text{min.}} = \frac{W A_p^{1/2}}{.782\ S_e} \text{ and hence } L/D_{\text{max.}} = \frac{.782\ S_e}{A_p^{1/2}} \qquad (4)$$

If Eq. (2) is multiplied by V and divided by 375, the expression for the thrust power required is

$$P_R = .00000872\, A_\rho \sigma V^3 + \left(\frac{W}{S_e}\right)^2 \frac{1}{3\sigma V} \qquad (5)$$

The Breguet formula for range is:

$$R = \frac{863 \times \eta_{max.}}{C} \times L/D_{max.} \times \log\,(1 + W_F/W_E) \qquad (6)$$

$\eta_{max.}$ = Average propeller efficiency.
C = Average specific fuel consumption—lbs./hp./hr.
W_F = Weight of fuel.
W_E = Gross weight less fuel.

A study of these four simple equations, Eqs. (3), (4), (5), and (6), brings out some interesting points regarding range and the cruising speed at maximum L/D.

(1) V increases inversely as the square root of the relative density.

(2) V varies only as the reciprocal of the fourth root of the parasite drag, so that large changes in A_ρ are required to affect V appreciably.

(3) Due to the fact that decreased fuel consumption and improved propeller efficiency decrease the fuel used and hence increase the weight at the end of the trip, they each will slightly improve $V_{average}$ if varied, favorably.

(4) V increases as the square root of the span loading but it is important to note that the power required varies with the square of the span loading.

(5) Theoretically, V varies inversely as the square root of the effective span. However, if some of the large fuel saving possible with increased span is used to fly at speeds greater than that of $L/D_{max.}$ such a change may increase both V and range substantially.

(6) The most economical speed is increased considerably when flying against a headwind, the power required to fly faster being counterbalanced by the shorter time which the airplane has to fly against the wind. The method of finding the correct speed is simple but time does not allow the presentation of the chart or equation here. For an airplane with a cruising speed of 135 m.p.h., a headwind of 30 m.p.h. increases the economical speed to 144 m.p.h. The increase is more on slower ships and less as the economical speed increases. The importance of high cruising speeds when flying against a headwind is clear due to the decreased percentage loss in effective speed. This constitutes one of the important advantages of a flying boat over a dirigible whose cruising speed is only half that of the airplane.

It is difficult to increase the true economical speed on a long range airplane because of its slow variation with parasite and the adverse effect of increased span. However, a large gain can be made by taking advantage of the relatively flat peak of the L/D curve. By flying at a higher speed where the L/D is 97.5% of the maximum the gain in speed is 11.2% with only a $2^1/_2$% sacrifice in range, and a power increase of 15%.

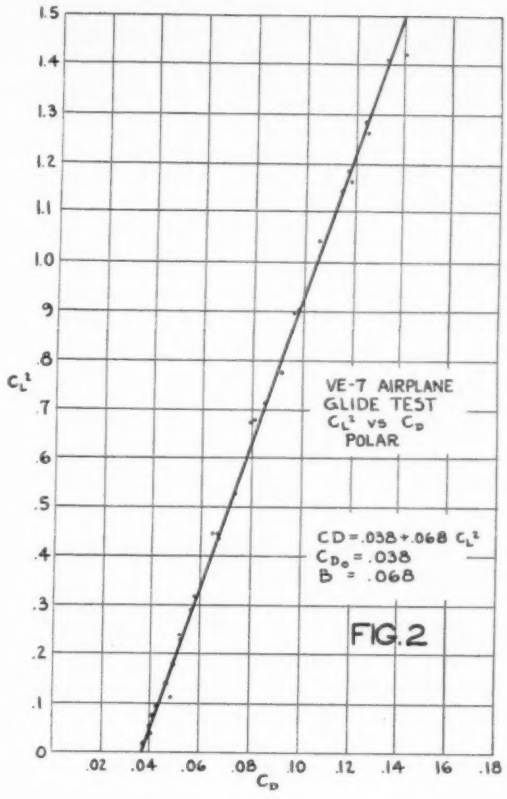

FIG. 2

It is an interesting point that at the speed of $L/D_{max.}$ the parasite drag exactly equals the induced drag, and at higher speeds the former predominates.

Having discussed the effect of various factors on economical cruising speed their effect on range as shown by Breguet's formula will be discussed.

(1) The range will increase directly as the propeller efficiency improves and the fuel consumption decreases. With a fixed pitch propeller the problem is simple and the results are pretty much beyond our control. With a constant speed propeller, on the other hand, the problem is quite complex because the propeller efficiency varies with both engine speed and power and with airplane speed while the specific fuel consumption varies with manifold pressure and engine speed. Usually engine manufacturers give only the specific fuel consumption determined from the basic propeller load curve starting from rated power and r.p.m. With a constant speed propeller it is not necessary and seldom desirable to throttle along this curve. There may be, as shown by Fig. 3, any number of such cubics giving constant power coefficient C_ρ starting at different points on the full throttle power curve. One engine manufacturer has made a thorough study of specific fuel consumption and found that the minimum specific fuel consumption at any power was obtained by following a line such as Line A of Fig. 3. Data for important engines sufficient to permit plots of contour curves

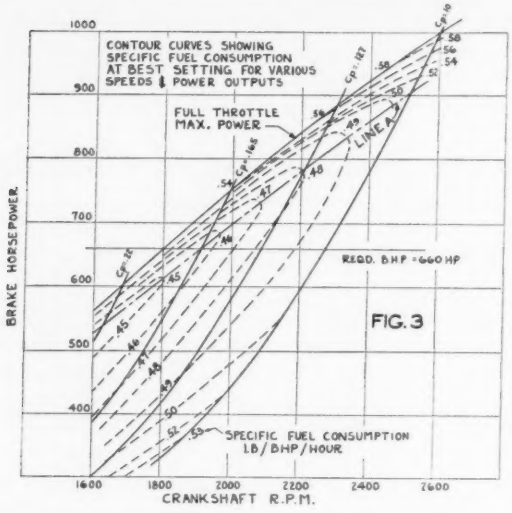

FIG. 3

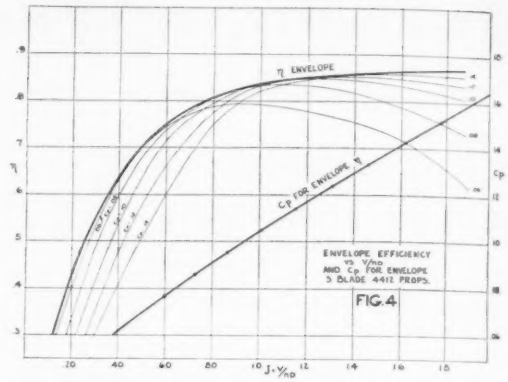

FIG. 4

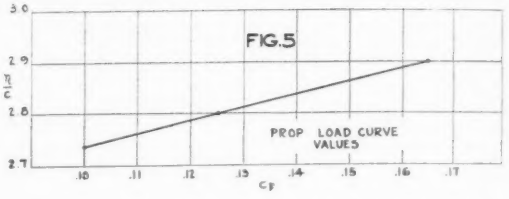

FIG. 5

of specific fuel consumption *vs.* engine power and speed are needed and must be had.

In a somewhat similar manner propeller efficiency at any V/ND will vary with power coefficient $C_p = P/\rho n^3 D^5$. At any V/ND there is a value of C_p giving the maximum value of η. Fig. 4 shows an envelope curve of propeller efficiency based on these values of C_p.

For any airplane speed, by use of charts such as just described, the engine speed at any power may be chosen to give the best ratio of values of η/C or propeller efficiency and specific fuel consumption. Fig. 5 shows the variation in η/C with C_p. On long trips such studies will result in very appreciable payload increases.

(2) The range does not vary directly as the amount of fuel carried but as the log $(1 + W_F/W_E)$. This relationship works out so that the greater the proportion of the gross weight is fuel the greater will be the range *per pound* of fuel. In a specific case, if the fuel weights are 40, 20, and 10 percent of the gross weight so that the ratios of fuel load to each other are 1.00, .50, and .25, the respective ranges are 1.00, .437, and .206. The reason for this of course is the effect of induced drag, it being the least at the end of the trip in the case of the ship with the most fuel at the start.

(3) The other factor to consider is the L/D, to which the range is directly proportional when the airplane is flying at economical speed. From Eq. (4) $L/D_{max.} = .782\ S_e/A_p^{1/2}$. Here the predominant influence of *effective* span on range is clearly brought out. Again it should be emphasized that not geometric but effective span is the criterion.

(4) In contrast, range varies inversely only as the square root of the parasite drag. This and the preceding paragraph are the explanation of the range records that have been established by large span airplanes, not particularly clean aerodynamically.

Lest a wrong impression be given, it should be stated that commercial operation, even over the ocean generally requires speeds appreciably in excess of the true economical speeds, and hence parasite drag becomes more important. Probably the best criterion for comparing various designs of long range airplanes is the formula—Factor of merit = payload × speed × range—taking into account the fundamentals of payload, range, and speed. This is also useful in studying the effect of varying the speed on payload with a given range.

The discussion above applies to airplanes of about the same size, whether large or small. Overshadowing in its effect all the factors mentioned above is that of mere size and weight. Assuming the same general type of design, increasing the size and weight has a major effect on range for the following reasons.

(1) The structural and power plant weights are a definitely decreasing percentage of the gross weight, up to the maximum we have investigated carefully, leaving a greater proportion of the gross weight available for fuel if the payload is maintained a constant percentage of the gross weight.

(2) Scale effect has a pronounced influence on the parasite drag.

(3) With increasing size, the ratio between the structural portion of the parasite drag and the part formed by the wing profile drag steadily decreases. In other words, the drag of the hull, engine nacelles, floats, and miscellaneous items such as radio antenna becomes relatively less with increasing size until the ideal of the flying wing is approached. An L/D of 12 to 14 is good for a flying boat with a gross weight of 25,000 lbs. while a value of 18 is possible with a 100,000 lb. airplane and an L/D of 20 or more should be attainable on a still larger ship.

(4) It has been pointed out above that range is directly proportional to L/D and hence to effective

span. With larger airplanes, the nacelles and body affect a much smaller proportion of the span so that the correction factor applied to geometric span becomes more nearly unity. This is an important secondary effect of increasing size.

(5) The trends just noted make it possible to increase the power loading as the size increases, thus completing the beneficent circle of decreasing power plant weight percentages and nacelle drag.

Not only range but cruising speed is greatly improved as the size becomes greater due to these factors.

(1) The span loading rises very rapidly with gross weight, and as shown by Eq. (3), the speed at $L/D_{max.}$ varies as $(W/S_e)^{1/2}$. Even with constant wing loading the span varies only as $W^{1/2}$, and since the wing loading varies nearly as $W^{1/2}$ the span loading will increase as $W^{3/4}$ and hence if the parasite drag is constant, V at $L/D_{max.}$ will increase as $W^{1/8}$.

(2) Although the total parasite drag increases with greater size it does so slowly and since speed at $L/D_{max.}$ is inversely proportional to only $A_p^{1/4}$, this does not nearly counterbalance the influence of the higher span loading. To assume that A_p varies as $W^{3/2}$ is a reasonable approximation. Hence the net variation of economical cruising speed with weight may be taken as $V \propto W^{5/16}$. If V is 140 m.p.h. for a 50,000 lb. airplane it will be 160 m.p.h. and 186 m.p.h. for a 100,000 lb. and 200,000 lb. airplane, respectively. If the latter is increased by 11.2% by flying at 97.5% of $L/D_{max.}$ as discussed above, the cruising speed is is 210 m.p.h.

The first section of this paper deals with the effects of several basic factors on the design of long range flying boats. The application of these principles to the determination of some of the main characteristics of a design will now be discussed briefly.

The first step in the problem is a statement of the limiting requirements such as length of trip, velocity of headwind, additional hours of fuel reserve, cruising speed, payload, and type of accommodations required for passengers and cargo. The last item is important as it greatly influences the size of hull and hence its drag.

In case the cost narrowly limits the size, or if the payload is more than 15 to 20 percent of the weight, in the case of the non-stop transatlantic run, then the amount of fuel is limited. The design is importantly affected by this, since it means that the airplane must be flown at close to economical speed with the emphasis on large span and moderate wing loading. The capacity of the airplane to do the given job is really the determining factor in setting wing and span loadings. When the size is not limited or when speed is considered of first importance, the emphasis shifts from considerations of induced drag to parasite drag. Flying speed will be well above that of $L/D_{max.}$. The span and wing loading can be increased. Flight will be made at nearly constant power and hence the speed at the end of the trip will be considerably greater than at the beginning, the reverse of the condition when flying at $L/D_{max.}$. As in the case of land transports, speed will be fixed by the limiting cruising power of the engines.

Knowing the condition of the problem, the designer can calculate rather readily by chart or formula the wing loading and span to give the optimum desired result. The important matter of plan form must now be decided Weight and structural considerations lead to a very high taper ratio. However, both theory and experiment have demonstrated the marked tendency with high taper ratios, for the wing tips to stall, resulting in loss of lateral control when it is most needed. It may be brought out that the higher the aspect ratio, the larger the taper ratio may be. With long range aircraft another element in this connection must be considered and that is the effect of plan form on lift distribution and induced drag. The factor e, which is determined by the slope of the C_D versus C_L^2 curve, and its use in obtaining the effective span has been discussed. To secure a high value of e means that the lift distribution or the wing plan form must approach the elliptical. Span gained through improvement in e is just as useful as if added geometrically. It must be remembered that if a wing is given an aerodynamic twist this will affect e adversely or otherwise. Another powerful factor determining e is the interference between the nacelles and the wing or the hull and the wing. If the juncture is bad there will be a double loss: increased parasite drag and serious disturbance of the circulation about the wing reflected in a large decrease in e and consequent lowering of L/D. The need of a perfect juncture and melding of the two flows about the body and about the wing is particularly critical if the proportion of the span occupied by the nacelles and the hull is large. The Short "Empire" boats are excellent examples of clean design but my feeling is that this basic point in proportion has not received sufficient attention and if they do not prove efficient for ocean work the author believes this fact will be the underlying cause.

The Balance of Vorticity in Parallel Shear Motion

C. L. PEKERIS, *Massachusetts Institute of Technology*

(Received March 12, 1937)

IN HIS paper in the February, 1937 issue of this Journal, Th. von Kármán[1] proves that the Reynolds energy integral for turbulent motion, which expresses the balancing between the space-integral of the energy of mean motion which is coverted into energy of turbulent motion, and the energy which is dissipated by turbulent motion, can be particularized to give a relation for the *local* balancing of energy. He also derives a second relation which expresses the local balancing of vorticity, namely,

$$-\frac{d}{dx_2}\left(\frac{1}{2}\overline{u_2'\omega'^2}\right)=\nu\sum_i\sum_k\overline{\left(\frac{\partial\omega_i'}{\partial x_k}\right)^2}. \quad (10)$$

Here x_2 denotes the direction normal to the mean motion and to the walls, which are situated at $x_2 = -h$ and $x_2 = h$, u_2' the component of fluctuating velocity in that direction, ω_i' the components of fluctuating vorticity and

$$\omega'^2 = \omega_1'^2 + \omega_2'^2 + \omega_3'^2.$$

In deriving this equation certain terms were neglected, but it appears that these terms become significant in the vicinity of the walls, where, as will be seen, all of the fluctuating vorticity originates. That Eq. (10), as it stands, is not applicable for the entire space can be seen readily by integrating it between $x_2 = -h$ and $x_2 = h$. The left hand side then vanishes on account of the vanishing of u_2' at the walls, while the right hand side, being an integral over a positive quantity and representing the total dissipation of turblent vorticity, cannot vanish. It is, however, possible to derive a relation for the balancing of vorticity *over the entire space*, in which the special conditions existing at the walls are brought into prominence.

Take the mean value of von Kármán's Eq. (8), which can be written as

$$\frac{1}{2}\frac{\partial\omega^2}{\partial t}+\sum\frac{1}{2}\frac{\partial}{\partial x_i}(u_i\omega^2)+\sum_i\sum_k\omega_i\omega_k\frac{\partial u_i}{\partial x_k}=\nu\sum\omega_i\Delta\omega_i \quad (8)$$

and integrate over x_2. If, as von Kármán does, the mean values of the triple products are neglected, the integral of the left hand side is zero. Now

$$\sum\overline{\omega_i\Delta\omega_i}=\frac{1}{2}\frac{d^2\Omega^2}{dx_2^2}-\left(\frac{\partial\Omega}{\partial x_2}\right)^2+\frac{1}{2}\frac{d^2\overline{\omega'^2}}{dx_2}-\sum_i\sum_k\overline{\left(\frac{\partial\omega_i'}{\partial x_k}\right)^2} \quad (1)$$

where Ω denotes the vorticity of the mean motion. Since the integral of Eq. (1) is zero

$$\nu\left(\frac{1}{2}\frac{d\Omega^2}{dx_2}+\frac{1}{2}\frac{d\overline{\omega'^2}}{dx_2}\right)\Big|_{-h}^{h}=\nu\int_{-h}^{h}\left(\frac{\partial\Omega}{\partial x_2}\right)^2dx_2+\nu\int_{-h}^{h}\sum_i\sum_k\overline{\left(\frac{\partial\omega_i'}{\partial x_k}\right)^2}\partial x_2. \quad (2)$$

The terms on the right hand side represent, respectively, the total dissipation of the vorticity of mean motion and of the turbulent vorticity, while the terms on the left hand side represent the supplies of vorticities at the walls. It can be shown, moreover, that the supply of mean vorticity at the walls is less than the total dissipation of mean vorticity and, therefore, that part of the dissipation of mean vorticity is accounted for by the supply of turbulent vorticity at the walls.

Then

$$\Omega=\frac{dU}{dx_2}=\frac{\tau}{\rho\nu}+\frac{\overline{u_1'u_2'}}{\nu}$$

and, since for parallel motion $\frac{d^2\tau}{dx_2^2}=0$,

$$\left(\frac{\partial\Omega}{\partial x_2}\right)^2=\frac{1}{2}\frac{d^2\Omega^2}{dx_2^2}-\Omega\frac{d^2\Omega}{dx_2^2}=\frac{1}{2}\frac{d^2\Omega^2}{dx_2^2}-\frac{1}{\nu}\frac{d}{dx_2}\left[\left(\frac{\tau}{\rho\nu}+\frac{\overline{u_1'u_2'}}{\nu}\right)\frac{d\overline{u_1'u_2'}}{dx_2}-\overline{u_1'u_2'}\frac{d}{dx_2}\left(\frac{\tau}{\rho\nu}\right)\right]+\frac{1}{\nu^2}\left(\frac{d\overline{u_1'u_2'}}{dx_2}\right)^2.$$

Remembering that both $\overline{u_1'u_2'}$ and $\frac{d\overline{u_1'u_2'}}{dx_2}$ vanish at the walls,

$$\nu\int_{-h}^{h}\left(\frac{\partial\Omega}{\partial x_2}\right)^2\partial x_2=\frac{\nu}{2}\frac{d\Omega^2}{dx_2}\Big|_{-h}^{h}+\frac{1}{\nu}\int_{-h}^{h}\left(\frac{d\overline{u_1'u_2'}}{dx_2}\right)^2dx_2. \quad (3)$$

The last term in Eq. (3) represents the difference between the dissipation of mean vorticity and its supply at the walls. In laminar flow it, of course, vanishes. With the aid of Eq. (3), Eq. (2) now can be written in the form

[1] Th. von Kármán, *The Fundamentals of the Statistical Theory of Turbulence*, pages 131–138, Journal of the Aeronautical Sciences, Vol. 4, No. 4, February, 1937.

$$\frac{\nu}{2}\frac{d\overline{\omega'^2}}{dx_2}\Bigg|_{-h}^{h} = \nu\int_{-h}^{h}\sum_i\sum_k\overline{\left(\frac{\partial\omega_i'}{\partial x_k}\right)^2}\,dx_2 + \frac{1}{\nu}\int_{-h}^{h}\left(\overline{\frac{du_1'u_2'}{dx_2}}\right)^2 dx_2. \quad (4)$$

Unlike the corresponding energy integral of Reynolds, Eq. (4) does not contain explicitly functions of the mean motion. This equation was derived only under the assumption that the mean values of the triple products in Eq. (8) are small. It is strictly true for two-dimensional fluctuating motion. It is seen from Eq. (4) that in a permanent turbulent régimé there is a steep gradient of turbulent vorticity at the walls. The shedding of turbulent vorticity at the walls is not only sufficient to make up for the total dissipation of turbulent vorticity but it also accounts for part of the dissipation of the mean vorticity. Thus it appears that within the fluid there is a conversion of turbulent into mean vorticity. It is clear that in considering the balancing of vorticity it is essential to recognize the process of the generation of turbulent vorticity at the walls.

Letter to the Editor

April 1, 1937

Dear Sir:

I have discovered an error in my article entitled "*The Next Five Years in Spark Ignition Aviation Engines*," published in the January 1937 issue of the Journal.

The necessary corrections are as follows:

(1) The last line of the left-hand column on page 115 should read:

"..... roughly proportional to the inverse *cube* root of the. . ."

(2) The fifth to eighth lines of the right-hand column on page 115 should read:

"..... surface. Combining these two considerations, a 'cooling factor,' proportional to the .53 power of the relative density times the ratios of the temperature difference at sea level and altitude can be derived. Fig. 3 shows this cooling factor as a ....."

Attached herewith is a new Fig. 3.

C. F. TAYLOR

Massachusetts Institute of Technology

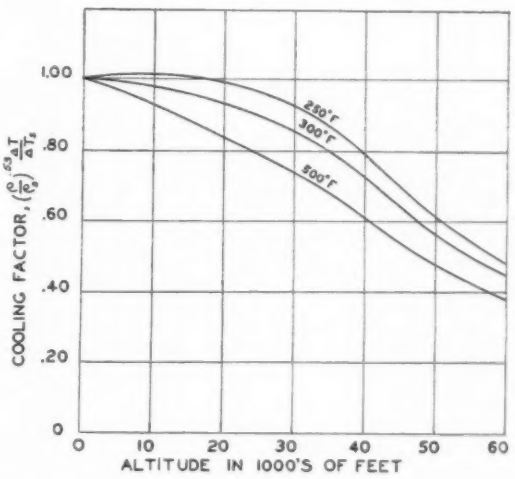

FIG. 3. Cooling factor for three different cooling-surface temperatures.

Torsion of 17ST Extruded Angles and Channels

LORETO LOMBARDI, *The Glenn L. Martin Company*

(Received February 24, 1937)

THE torque on any section may be expressed by:

$$T = KG\frac{\theta}{L}$$

where

T = the twisting moment in inch pounds
G = the modulus of rigidity
θ/L = the unit angle of twist in radians per inch
K = a torsion constant

Experimental values of the torsion constant, K, have been obtained by the author and J. Chapper from tests made on 17ST aluminum angles and channels suitable for aircraft use and are compared, in Table 1, with those obtained from two formulas commonly used in aeronautical design; one by Timoshenko in his "Strength of Materials" Vol. 1, and the other by Trayer and March in N.A.C.A. Technical Report No. 334.

The apparatus used for the tests was a Riehle

TABLE 1

Tabulation of Results[1]

Angles

Thickness		Overall		Fillet Radius	$K \times 10^3$			% Difference	
Long Leg	Short Leg	Long Leg	Short Leg		Test	Trayer and March[2]	Timoshenko[3]	Trayer and March	Timoshenko
.1875	.1875	1.00	1.00	.125	3.850	3.758	3.74	−2.4	−2.85
.1875	.1875	1.25	1.25	.125	5.176	4.839	4.84	−6.5	−7.3
.1875	.1875	1.50	1.50	.125	6.100	5.930	5.95	−2.6	−2.45
.1875	.1875	2.00	2.00	.125	8.176	8.123	8.11	−0.66	−0.81
.1875	.1875	2.50	2.50	.125	11.32	10.277	10.45	−9.2	−7.7
.1875	.1875	1.50	1.25	.125	5.867	5.387	5.45	+7.65	+5.96
.1875	.1875	1.75	1.25	.125	5.730	5.946	5.95	+3.41	+3.48
.1875	.1875	2.00	1.50	.125	6.793	7.034	7.04	+3.54	+3.64

Channels

Thickness		Overall		Fillet Radius	$K \times 10^3$			% Difference	
Both Legs	Back	Both Legs	Back		Test	Trayer and March[2]	Timoshenko[3]	Trayer and March	Timoshenko
.125	.125	1.00	1.00	0	1.643	1.775	1.792	+ 8.05	+ 9.06
.125	.125	1.00	1.50	0	2.400	2.100	2.118	−12.5	−11.8
.125	.125	1.00	1.75	0	3.005	2.259	2.279	−24.6	−24.0
.125	.125	1.00	2.00	0	3.183	2.42	2.445	−24.0	−23.0
.125	.125	1.50	1.50	0	3.375	2.744	2.769	−18.7	−18.0
.125	.125	1.50	2.50	0	4.62	3.391	3.419	−26.5	−26.0
.125	.125	1.50	3.50	0	6.57	4.035	4.065	−38.5	−38.1

[1] From an M.I.T. 1936 thesis by the author and J. Chapper.

[2] George W. Trayer and H. W. March, *The Torsion of Members Having Sections Common in Aircraft Construction*, pages 26–31, N.A.C.A. Technical Report No. 334, 1929.

[3] S. Timoshenko, *Strength of Materials*, Vol. 1, pages 77–81, D. Van Nostrand Company, 1930.

Torsion Testing Machine having a capacity of 60,000 in. lbs. Two cast iron holders were used to grip the specimens, which were placed in the holders so that their centres of gravity coincided with the axis of rotation of the machine, and then cast into place with lead. It was found that having the centre of gravity of the specimen coincide with the axis of rotation of the testing machine was more important than trying to obtain undue refinement in reading angles of twist, since the specimens that were centered properly reached a maximum load with little or no buckling, while those that were slightly off centre started buckling under very low loads. Buckling of the test specimen during testing is undesirable as it throws the machine out of line and casts some doubt on the accuracy of the load readings. In an actual structure it would be undesirable because of its weakening effect on the members themselves.

From an inspection of the tabulated results, it appears that there is not much choice between the two formulas as far as accuracy is concerned. A timely observation is that Timoshenko's remark about his method being applicable only to compact sections was emphatically borne out by the tests.

Since it is much less laborious to use Timoshenko's method, and since the results differ so little, it is suggested that his method be used in the design of angles and channels. However, either method must be used with some discretion if the section in question is not reasonably compact.

Institute Notes

Luncheon in Honor of C. R. Fairey

A luncheon, in honor of C. R. Fairey of London, was given by the Institute at the Waldorf-Astoria Hotel in New York on March 23, 1937. Other guests were Algernon Maudsley, Major B. Heckstall-Smith, and A. Mylne, yachting officials of Great Britain, who accompanied Mr. Fairey to the United States to discuss with the New York Yacht Club a change in the rules for the America's Cup. Group Captain T. E. B. Howe, British Air Attache; C. L. Powis of Phillips and Powis, Ltd., and Richard Fairey also were guests.

General G. A. Crocco

The presentation of the certificate of Honorary Fellow of the Institute to His Excellency General G. A. Crocco of Italy was made by R. R. Loening at a luncheon at the Palazzo Ambasciatori in Rome on February 15, 1937.

Mr. Loening, in his address of bestowal, said in part:

"The Institute represents the center in which is gathered all that is finest, most active, and most advanced in the carrying on and development of the aeronautical sciences in the United States. It is highly valued by all those who are leaders in this new, complex, and modern science. Its members represent the best in all the fields which this science covers. It creates the standards which control the field and its members are zealous that these shall always be of the highest.

"In the United States individuals in the field who have performed service of outstanding excellence receive special recognition and are honored thereby.

"The distinction of Honorary Fellowship for foreign members is limited to one selection for each year. It is now a pleasure to welcome into this distinguished group one who is outstanding in the development of aviation in Italy.

"General Crocco, your achievements have brought you acclaim beyond the borders of your native land. It has brought you the highest esteem in the aeronautical profession in the United States. In recognition of your eminent services the Institute of the Aeronautical Sciences has elected you an Honorary Fellow."

Among those present at the luncheon were Colonel George H. Paine, Air Attache of the U. S. Embassy, Rome; Major Norman E. Fiske, Assistant U. S. Military Attache; Captain Thomas D. White, Assistant U. S. Military Attache; L. C. Wickersham, U. S. Embassy; Professor Tullio Levi-Civita; Professor Lucio Silla; Colonel Fernando Bertozzi-Olmeda; Ing. Luigi Crocco; General Raffaele Giacomelli; Ugo Rampelli, and Anastasio Anastasi.

Films of European Laboratories

The films of European laboratories and wind tunnels which were presented to the Institute by the governments of England, Germany, and Italy, have been shown at the California Institute of Technology, Stanford University, the University of California; to The Aircrafters, and at the Washington Meeting of The Society of Automotive Engineers. They will be shown at Wright Field by the Engineering Division of the Air Corps on April 3, and at the National Research Council in Ottawa on April 15.

Student Branches

University of Michigan. A meeting of this Student Branch was held on Thursday, March 11. About thirty-five members attended. Plans were discussed for holding an Engineering Open House this spring during the University of Michigan Centennial, which is being celebrated this year. All departments of the Engineering College are expected to participate, and the Student Branch of the Institute will be responsible for exhibits representative of aeronautics. Details of a proposed trip to both the Stinson Aircraft Corporation and the Wayne County Airport on March 13, were discussed, as were plans for visits to the Barkley-Grow plant and the Detroit Municipal Airport. R. W. Ayer, Chief Engineer of the Stinson Aircraft Corporation, was introduced as the speaker of the evening. Mr. Ayer discussed engineering problems of airplane design and showed some interesting pictures he had taken.

University of Minnesota. At the invitation of the Flying Club, the members of this Student Branch attended a meeting on March 3. A lecture was given by Dr. and Mrs. Jean F. Piccard on "The Personal and Scientific Side of Stratospheric Explorations," and motion pictures of their stratospheric flight were shown. A meeting of this branch was held in the main Engineering Building on March 5, at which a talk on the flight training course offered by the U. S. Marine Corps and the U. S. Navy was given by Captain C. J. Schlapkohl of the U. S. Marine Corps. He told of the qualifications of an aviation cadet and of the types of training received at Pensacola. On Wednesday, March 24, thirty-four senior students of the University visited the Institute on their Spring inspection trip.

Letters to the Editor

March 5, 1937

Dear Sir:

The Massachusetts Institute of Technology will shortly start the construction of a high-performance wind tunnel to be dedicated as a memorial to the Wright Brothers. Gifts from persons interested in the advancement of aeronautics have made this possible.

With the increasing speed and size of aircraft, our existing wind tunnels have become obsolete. In this country, only the great Langley Memorial Laboratory of the National Advisory Committee for Aeronautics has equipment operating near "full scale" Reynolds Number.

The scale effect in model testing depends on the Reynolds Number, the product of velocity and wing chord divided by kinematic viscosity. The Reynolds Number of airplanes has increased more than 200 percent since 1918 and this growth rate may be expected to continue. Model data to be safely extrapolated should be taken for conditions corresponding to a Reynolds Number above 10^6.

The power required to obtain the wind in a tunnel varies as the cube of the velocity, the square of the diameter, and as the density. It is, therefore, more economical to obtain high Reynolds Number by increasing density than by increasing speed or size.

The projected Wright Brothers' wind tunnel will be a closed circuit of welded ship steel with external frames. Pumped up to 4 atmospheres pressure, the Reynolds Number will be about 6×10^6. The throat of the Venturi section will be an ellipse of 10 ft. major axis, suitable for models of the order of 7 ft. in span. A 2000 hp. steam turbine will turn the fan.

The same tunnel when pumped out to 1/4 atmosphere pressure, corresponding to about 35,000 ft. altitude, will have a wind velocity of 400 m.p.h. Aerodynamic research at such a speed is considered necessary if future airplanes are to fly in the substratosphere.

The projected tunnel will be unique in that it combines means for operating at a high Reynolds Number to study phenomena of skin friction, turbulence, and flow separation, as well as means for the study of high velocity phenomena. It is considered probable that changes in the design of wings must be made when the air speed is such that local velocities approach the velocity of sound.

Due to the use of a variable pressure, access to the model in the tunnel will be extremely inconvenient, and a new type of suspension of the model has been devised by means of which electrical measuring instruments outside the tunnel will indicate the aerodynamic force of the wind on the model. The principle of these balances is that of the well-known electro-magnetic micrometer, by which a very small displacement of an elastic element unbalances the magnetic flux in an air gap, giving rise to unbalance in an A.C. bridge circuit.

J. C. HUNSAKER
Massachusetts Institute of Technology

March 3, 1937

Dear Sir:

In the Journal for October, 1936, there is a paper on the "Effect of Rivet Spacing on Stiffened Thin Sheet in Compression" by W. L. Howland. The paper includes a formula from which the rivet pitch may be determined if the thickness of the sheet be known and the stress to which it is to be worked. The formula is developed by strain-energy equations but leads to a result which is in no way different from that obtainable by using Euler's equation for a fixed-ended column, which may be written

$$f = \frac{C\pi^2 E}{(L/\rho)^2} \qquad (1)$$

When $C = 4$ and $\rho^2 = t^2/12$ this expression takes the same form as Howland's in that it may be written

$$L = 1.814\, t\sqrt{E/f} \qquad (2)$$

Since Euler's formula becomes of doubtful value in the design of compression members when the stress, f, exceeds about half the yield point of the material it would seem advisable to use Howland's equation for values of f of 20,000 lb. per sq. in. or less, when the modulus of elasticity is taken at 10,000,000 lb. per sq. in. for the aluminum alloys. For higher stresses E should be reduced so that Eq. (1) above yields values of f comparable with those given by Johnson's Parabolic Formula by one of the standard Straight-Line formulas or other recognized expressions for determining allowable stresses on short columns. Mr. Howland, however, appears to have used an unmodified E in drawing the curves for required rivet pitch when the joint is to carry stresses of 30,000 or 40,000 lb. per sq. in. so that the results given by the curves in his paper are on the unsafe side and should not be used in the design of aircraft structures.

Fig. 1 is based on Eq. (2) above with the value of E so modified that f computed from Eq. (1) would be the same as that given by Johnson's Parabolic Formula with a fixity coefficient of 4.

To use the figure one enters at the left with the stress for which the joint is to be designed and proceeds horizontally to the curve representing the yield point for the aluminum alloy in hand, thence vertically to the line representing the sheet thickness. A horizontal line from that point to the scale at the right gives the rivet pitch required. For conservative design the pitch should be taken as the distance between the centers of rivet holes. There is some evidence, in the form of past experience rather than quantitative test data, which appears to justify the use of the distance between the edges of adjacent holes instead of between the centers when round or brazier head rivets are used but it is hardly adequate to permit making the recommendation that this be done in all cases.

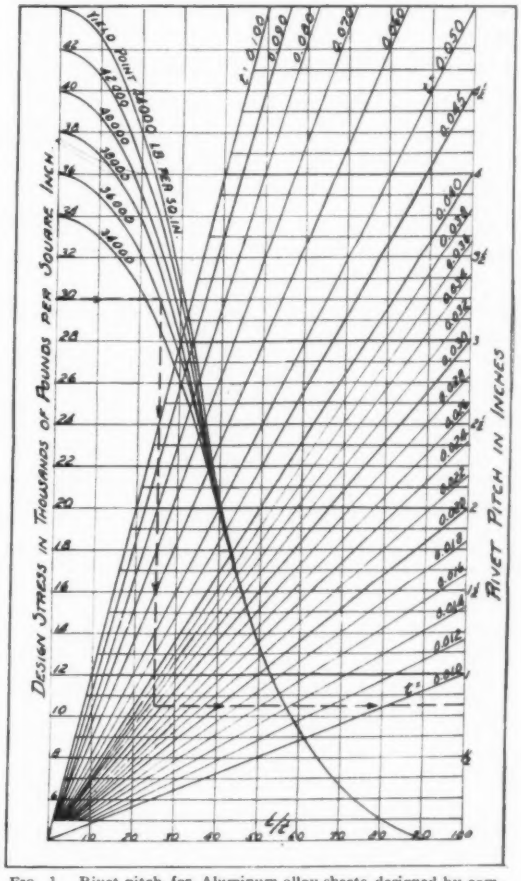

FIG. 1. Rivet pitch for Aluminum alloy sheets designed by compression load requirements.

It is desirable that further work be done to establish the factors affecting rivet pitch on joints between sheets and stiffeners, flanges and cover plates, and similar connections between elements carrying equal, or nearly equal, compressive stresses. Mr. Howland's tests check his figure and mine in the region where the design stress is 20,000 lb. per sq. in. but I know of no data from which the dependability of either figure may be determined for stresses between 30,000 and 40,000 lb. per sq. in.

JOSEPH S. NEWELL
Massachusetts Institute of Technology

Exchanges

The Institute exchanges the Journal with many other aeronautical periodicals. They are kept on file at the Skyport in Rockefeller Center, New York City, where members may read them. As readers of the Journal may wish to subscribe to some of them, a list of these periodicals with their addresses is published here. Information regarding subscription prices may be secured from the Secretary of the Institute.

Aero, Maneesikatu 2, Helsingfors, Finland.

Aero Digest, 515 Madison Ave., New York City.

Aeronautica Argentina, Velez Sarsfield 57, Cordoba, Argentina.

L'Aéronautique, 55 Quai des Grands-Augustins, Paris, France.

L'Aérophile, 7 Rue Sainte-Lazare, Paris, France.

The Aeroplane, 175 Piccadilly, London, W.1, England.

L'Aerotecnica, Via delle Coppelle 35, Rome, Italy.

Les Ailes, 77 Boulevard Malesherbes, Paris, France.

Aircraft Engineering, 2 Bloomsbury Place, London, E.C.1, England.

Air Law Review, Washington Square East, New York City.

Asas, Caixa Postal 1967, Rio de Janeiro, Brazil.

Astronautics, American Rocket Society, 31 West 86th Street, New York, N. Y.

Aviation, 330 West 42nd St., New York City.

L'Aviazione, Corso Umberto 504, Rome, Italy.

Boletin de Aeronautica Civil, Calle Azcuenga 923, Buenos Aires, Argentina.

Boletin Oficial de la Direccion General de Aeronautica, Magdalena 12, Madrid, Spain.

Bulletin du Service Technique de l'Aéronautique, 72 Chaussee de Waterloo, Rhode-Saint-Genese, Belgium.

Bulletin of the American Meteorological Society, Blue Hill Observatory, Milton, Massachusetts.

Bulletin Officiel du R.A.A., 6, Rue du Mezieres, Paris (6), France.

Bulletin Technique du Bureau Veritas, 31 Rue Henri-Rochfort, Paris (17), France.

Canadian Aviation, Journal Building, Ottawa, Canada.

Contact, Fort Lee, N. J.

Deutsche Luftwacht, Schoeneberger Ufer 46, Berlin W35, Germany.

Les Fiches Aéronautiques, 6 Rue Galilee, Paris, France.

Flight, Dorset House, Stamford St., London, S.E.1, England.

Flugwesen, Konviktska 22, Prague 1, Czechoslovakia.

Indian Aviation, P. O. Box 2361, Calcutta, India.

Interavia, 13, Corraterie, Geneva, Switzerland.

Journal of Air Law, Northwestern University, Chicago.

Journal of the Institute of Engineers, Australia, Science House, Gloucester and Essex Sts., Sydney, N. S. W., Australia.

Journal of Research of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Journal of the Royal Aeronautical Society, 7 Albemarle St., Piccadilly, London, W.1, England.

Journal of Scientific Instruments, 1 Lowther Gardens, Exhibition Rd., London, S.W.7, England.

Journal of the Society of Automotive Engineers, 29 West 39th St., New York City.

Letectvi, Celetna 13, Praha I, Czechoslovakia.

Luftfahrt-Forschung, Verlag Oldenbourg, Munich 1, Germany.

Die Luftreise, Lindenstr. 35, Berlin SW68, Germany.

Luftfahrt-Literaturschau, Z.W.B. bei der D.V.L., Berlin-Adlershof, Germany.

Model Airplane News, 551 Fifth Avenue, New York City.

Model Aviation, The American Academy for Model Aeronautics, 1733 RCA Building, Rockefeller Center, New York, N. Y.

Monthly Weather Review, U. S. Dept. of Agriculture, Washington, D. C.

Motor and Flying, 24 Bond St., Sydney, N. S. W., Australia.

National Aeronautic Magazine, Dupont Circle, Washington, D. C.

Official Aviation Guide, 608 S. Dearborn St., Chicago, Illinois.

The Pilot, Grand Central Air Terminal, Glendale, California.

Il Politecnico, Via Spiga 32, Milan (2/7), Italy.

Popular Aviation, 608 S. Dearborn St., Chicago, Illinois.

Proceedings of Institute of Radio Engineers, 330 W. 42nd St., New York City.

Publications Scientifiques et Techniques du Ministère de l'Air, 55 Quai des Grands-Augustins, Paris, France.

Review of Scientific Instruments, 175 Fifth Ave., New York City.

Revista de Aeronautica, Ministerio de la Guerra, Apartado 1047, Madrid, Spain.

Revue de l'Armée de l'Air, 55 Quai des Grands-Augustins, Paris, France.

Revue du Ministère de l'Air, 71 Avenue des Champs-Elysees, Paris, (8), France.

Rivista Aeronautica, Ministero dell'Aeronautica, Rome, Italy.

The Royal Air Force Quarterly, Gale & Polden Ltd., 2 Amen Corner, London, E.C.4, England.

Schweizer Aero-Revue Suisse, Gubelhangstrasse 22, Zürich-Oerlikon, Switzerland.

Soaring, 1614 Delaware Ave., Wilmington, Del.

Southern Flight, Ledger Building, Fort Worth, Texas.

Sportsman Pilot, 515 Madison Ave., New York City.

Technical News Bulletin of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Techniczne Nowosci Lotnicze, Czerwonego Kryza 21/23 m.6, Warsaw, Poland.

Technika Vosdushnogo Flota, U1. Radio 16, Moscow 16, U. S. S. R.

La Technique Aéronautique, 2 Rue Blanche, Paris (9), France.

U. S. Air Services, Transportation Building, Washington, D. C.

Western Flying, 420 S. San Pedro St., Los Angeles, California.

Wirtschaft Technik Verkehr, Alte Jakobstr. 148/155, Berlin SW68, Germany.

Zeitschrift für angewandte Mathematik und Mechanik, Kulmstr. 1, Dresden A24, Germany.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps.

Aerodynamics

Research in Fluid Mechanics. M. P. O'Brien and R. G. Folsom. Selected articles are summarized to indicate the progress in fluid mechanics since January, 1935, dealing with turbulence, pipe flow, metering, pitot-tube standardization, airfoils, and hydraulic machinery. Jour. Applied Mechanics, December, 1936, pages A141–A145. 1 table.

Aerodynamic Tunnels for High Velocities. J. Ackeret. Purpose of the high-speed wind tunnel, wind tunnels for subsonic velocities, and supersonic wind tunnels for ballistics are discussed. Theory, various designs, and equipment are considered in detail with many drawings of the designs described. A high-velocity wind tunnel operated by a 25,000-hp. steam turbine is proposed and the Velox steam turbine and boilers as well as the design of the tunnel are illustrated. Long paper. Presented before the Volta Congress. L'Aerotecnica, December, 1936, pages 885–925. 48 illus.

The Compressed-Air Wind Tunnel at Goettingen. H. Winter. Long description from Luftwissen, September, 1936. L'Aerotecnica, December, 1936, pages 970–975. 6 illus., 1 table.

The French N.A.C.A. New French organization for aeronautical research and general inspection is described. Les Ailes, January 28, 1937, page 4.

The Part Played by Skin Friction in Aeronautics. F. W. Lanchester. Early work of Froude, relation of skin friction to resistance arising from other causes, the Langley fallacy, Reynolds number and the condition of laminar flow (expressed graphically), resistance as a function of velocity, and ichthyroid or streamline bodies (as exemplified in the Graf Zeppelin airship) are reviewed in Part I.

The discussion on the economics of flight in the second section takes up aerodynamic resistance and the Newtonian principle, application of this principle to the vortex theory, elementary equations arising from Newtonian dynamics, difficulty of application, the importance and definition of the peripteral area, and the author's propositions concerning the economics of flight.

Part III is devoted to the vortex theory of sustentation and given a historical sketch with references, earlier and later methods of treatment, agreement demonstrated, and distribution of airfoil load grading.

Part IV deals with application of the author's theory at high Reynolds numbers and covers a comparison of theory and practice, examples from determinations made in the N.P.L. compressed-air tunnel, equations required, examples taken and data of the R.A.F. 48, Clark Y.H., and Goettingen 387, tabulated comparisons and graphic representation, efficiency as a criterion, and an estimate of limit of performance. Application of the author's theory at low Reynolds numbers is discussed in the last section and includes: the sailplane as a border-line case, bird flight and the Reynolds numbers, model used by the author, his 1894 airfoil, with data and N.P.L. test figures, early R.A.F. models tested at the N.P.L., data given, and efficiencies calculated. Jour. Royal Aeronautical Soc., February, 1937, pages 68–113 and (disc.) 113–131. 35 illus., 19 tables, 19 equations.

Scientific and Industrial Research. The report of research carried on in the Aerodynamics Department of the National Physical Laboratory refers briefly to results of investigations made in the compressed-air tunnel on the effect of surface roughness on the behavior of air foils, to calculations made of the effect of flexural elasticity of the wings on the loading due to sudden gusts, and a gust recorder. Fuel research on the production of active carbon from coal is also described. Review of Report of the Department of Scientific and Industrial Research for 1935–36. Engineer, February 12, 1937, pages 190–191.

Testing a Wind Tunnel. S. Hoerner. Tests and structural changes which were made on the wind tunnel of the Flugtechnischen Institutes der Technischen Hochschule Braunschweig after the tunnel was placed in operation. The tunnel is of the Goettingen type free jet with closed return. Performance requirements of the tunnel, guide veins of the return-flow channel, nature of the flow in the test section, character of the jet flow, and transition of the stream into the receiving channel are discussed. Luftfahrtforschung, January 20, 1937, pages 36–43. 12 illus., 2 tables.

Aircraft Design

Appreciation of the Aerodynamic Qualities of Airplanes. M. Precoul. Method developed for the calculation of the three principal aerodynamic characteristics of an airplane. The efficiency of any airplane may be rapidly evaluated from the three coefficients proposed which are related directly to these characteristics from the simple data easily found for all airplanes. These coefficients are: the coefficient of fineness or of aerodynamic efficiency, the drag coefficient, and the coefficient of speed range and maximum lift. Formulas for altitude corrections for these three coefficients are also given.

The formulas are applied to six different categories of airplanes, namely private airplanes with power above 100 hp., light airplanes with power below 100 hp., racers, military pursuit airplanes, transports, and large private airplanes and small transports. Characteristics are given in tables for a number of airplanes of each type. The pursuit airplanes include the Mureaux 170, Morane 275 and 325, Blériot 91/8, Dewoitine 371 and 511, Loire 250, Hanriot 110, Armstrong-Whitworth XXXV, Hawker Fury, Fokker D.21, Fiat CR-32, Caproni CH-1, Letov 231, and P.Z.L.24. The only American airplanes included are racers and transports. L'Aéronautique, L'Aérotechnique Sup., December, 1936, pages 145–154. 11 illus., 10 tables, 19 equations.

Ocean Air Transportation. L. C. McCarty, Jr. "Cruising speeds will increase greatly with 300–325 m.p.h. as a perfectly feasible limit in the not too distant future, and with 200–250 m.p.h. as an economic operating speed in the more immediate future." The trend in establishing the limitation of landing speed for the larger transoceanic flying boats with reference to seaworthiness, general safety, and the burden upon piloting technique is indicated.

Important requirements for aircraft in regular transoceanic service, as determined by experience, characteristics, and performance of flying boats in the transoceanic service of various countries at the present time and near future, passenger comfort and accommodations, superiority of large flying boats over large landplanes, the safe limit for landing speeds, and the probability of forced landing due to mechanical failure of the power units are considered.

Progress to date in ocean flying, outstanding advantages of Baltimore as the American terminus for mail, passenger, and express air service to Europe, either direct or via Bermuda, and North Atlantic routes are also discussed. The author is Project Engineer, The Glenn L. Martin Company. S.A.E Preprint for meeting January 11 to 15, 1937, 17 pages, 6 illus., 4 equations.

Problems in Design and Construction of Large Aircraft. R. J. Minshall, J. K. Ball and F. Plaudan. (See TECHNICAL DATA DIGEST, December 15 issue for review of preprint.) Discussions given with the paper are entitled "Compares Various Methods of Solving Problems," E. F. Burton and "Two Controversial Points Discussed," E. G. Reid. S.A.E Jour. (Trans.), February 1937, pages 67–80. 22 illus., 3 tables.

Slotted Wings. Various methods for improving the aerodynamic qualities of wings by control of the boundary layer are described including those developed by J. Angeli, M. Fauvre, Ackeret, Betz, Schrenk, M. J. Bamber, R. Maloy, and A. Lippisch. Les Ailes, January 28, 1937, page 7. 3 illus.

Drag of Fuselages with Various Contours. H. De Cenzo and E. Rooney. A shape for a cabin fuselage which would offer minimum resistance to airflow was the object of the described tests undertaken at the University of Detroit. Twelve forms of engine, fuselage and windshield arrangements were tested in the 7 × 10 ft. wind tunnel. The contours were made by a combination of models of two aft sections of fuselage, a cabin, three windshields, and inline and radial aircooled engines. With the inline engine the convex fuselage was found to have the advantage in reduced drag while with the radial the concave fuselage was superior. Aero Digest, February, 1937, pages 38 and 40. 10 illus., 1 table.

How Far? W. C. Rockefeller and N. B. Moore. Ultimate maximum range of aircraft. An airplane capable of a 12,450-mile range will not be impossible some day. For practical purposes long range must finally be combined with high speeds and the answer lies in higher altitudes. The difficulty of increasing present-day values of the maximum lift-drag ratios by any extremely large amount, and the fuel and oil weight ratios required for various maximum ranges are discussed. Continuation. Aviation February, 1937, pages 30–31, 75. 4 illus.

Improved Lateral Control. P. P. Nazir. Principal advantages of the cut slot and trailing flap control combination as compared to existing control devices. System of control at all speeds, effect of control of stalling of tapered wings, sucking away the boundary layer, discovery of the existence of an "air circuit" around the wing, results of tests of control under practical conditions of operation, full rolling moment comparison of both ailerons on a tapered wing, comparison of air flow around the slotted and Nazir flaps, five types of stalls occurring on wings, and their remedies. Concluded. Flight, Aircraft Engineer Sup., January 28, 1937, pages 1–6. 9 illus., 1 table.

Forced Vibration in Nonlinear Systems with Various Combinations of Linear Springs. J. P. DenHartog and R. M. Heiles. Single-mass systems containing a combination of linear springs are analyzed. Jour. Applied Mechanics, December, 1936, pages A127–A130. 10 illus.

How Hard Is a Bump? R. V. Rhode. E. P. Warner's review of a paper entitled "Gust Loads on Airplanes," which was presented before the S.A.E. (Preprint obtainable from the Editorial Unit.) Aviation, February, 1937, pages 32–33, 69. 2 illus.

Stability of Rectangular Plates under Shear and Bending Forces. S. Way. Problem of a plane simply-supported rectangular plate loaded by shearing forces in the plane of the plate on all four edges. In the second problem considered a plane simply-supported rectangular plate is loaded by uniformly-distributed edge shearing forces in the plane of the plate and linearly distributed tension and compression in the plane of the plate at the ends. Jour Applied Mechanics, December, 1936, pages A131–A135. 4 illus, 10 tables, 16 equations.

Two- and Three-Dimensional Cases of Stress Concentration, and Comparison with Fatigue Tests. R. E. Peterson and A. M. Wahl. Discusion of paper published in the March, 1936 issue and the author's reply. Jour. Applied Mechanics, December, 1936, pages A146–A150. 5 illus., 2 tables, 4 equations.

Sucking Off the Boundary Layer. B. S. Shenstone. Practical application of boundary-layer control. Effect of boundary-layer suction on top-speed performance is explained and what might be expected as a result of removing the boundary layer by suction is discussed for the case of the DeHavilland Comet airplane. Application of the air sucked in to cool the motors and to give additional thrust, and use of the same blowers also for supercharging are suggested. As the maximum lift coefficient of the wing could be tripled by the use of suction, wing area and empennage area could be made one-third the size for the same landing speed. The resulting machine should then have a top speed of about 420 m.p.h. Aeroplane, Aeronautical Engg. Sup., January 27, 1937, pages 98–100. 3 illus., 1 table.

When Will We Make 500 Km. Per Hour? Suggestion for increasing the average speed of airplanes to 500 km. per hour and arguments for and against stratosphere airplanes. Opinions of A. C. Crocco, G. G. Casiraghi, P. L. Weiller, F. R. Newton, P. Gianferrari, P. Nuvoli, H. Cornelius, W. Mittelholzer, I. Sikorsky, E. Amstotz, U. Savoia, and C. Rosatelli are quoted. Abstract from L'Ala d'Italia. Les Ailes, December 17, 1936, page 5.

Rotary Wing Aircraft

The Paradox of the Helicopter: Power Required Decreases as the Speed Increases. G. C. Richards. Richards helicopter designed on the principle of wings rotating on circular paths. Incidence of the blades of the variable-pitch lifting propeller changes periodically during rotation according to a circular distribution, and at each rotation a type of regular beating produces both lift and traction at the same time. Results of tests carried out in the large wind tunnel of the Service Technique. Les Ailes, January 7, 1937, page 8. 6 illus.

Problems of the Helicopter. H. G. Kuessner. Principal problems in helicopter development in regard to lifting force, flight performance, stability, and drive. A complete solution is given for the stability of helicopters with rigid blades and lifting surfaces. The rotor drive for a single lifting propeller without the use of auxiliary propellers is considered and its efficiency computed. Report of the Aerodynamischen Versuchsanstalt Goettingen. Luftfahrtforschung, January 20, 1937, pages 1–13. 9 illus., 4 tables, 40 equations.

Stress Analysis and Structures

Recent Research in Aircraft Structures. D. Williams. Tubes of rectangular cross section under torque loads, and stress distribution in thin-walled tubes and channels subjected to bending without twisting are considered in the first issue.

The "Hardy-Cross" method in relation to the stress calculation of rigid-jointed frames, design of beam webs as affected by Wagner's tension field theory, and the synthesis and analysis of simply-stiff frameworks are discussed in the second issue. To be continued. Engineer, February 12, 1937, pages 177–180. 12 illus.

The Calculation of Dampers for Systems Subject to Self-Induced Vibration. J. G. Baker and S. J. Mikina. The time-displacement curve for the building up of a self-induced vibration is shown to be a convenient basis for calculating the amount of damping required to prevent the vibration from building up. Starting transient of self-induced vibration, the case of transmission-line vibration due to sleet and wind, and damper design are discussed. Jour. Applied Mechanics, December, 1936, pages A-121–A-126. 15 illus., 15 equations.

Elastic Systems with Infinite Superabundant Connections. C. Minelli. The theory of virtual work is applied, by means of variational calculations, to investigations of the condition for deformation in systems with infinite elastic superabundant connections. From the condition of deformation, the condition for tension is easily set up. The method proposed is employed for the calculation of typical structural problems. L'Aerotecnica, November, 1936, pages 802–819. 8 illus., 1 table, 67 equations.

The Flexural-Torsional Oscillations of a Wing in a Uniform Current. P. Cicola. Conditions of stability for the flexural-torsional vibrations of a wing of finite span are set forth and a graphical procedure is indicated for the determination of critical speed, frequency of oscillation, and the ratio of amplitude and phase of the motion components. Results of tests are compared with those obtained in experiments at Turin. A graph is presented for the rapid calculation of critical velocity. Stability for systems without internal friction is analyzed. L'Aerotecnica, November, 1936, pages 785–801. 8 illus., 5 equations.

Canada

CCFN-1 Trainer. Two-place sesquiplane produced by the Canadian Car and Foundry Company may be powered by either the 100- or 125-hp. Kinner or the 145-hp. Warner engine. With a Warner engine, maximum speed is 136 m.p.h. Construction and characteristics. Aviation, February, 1937, page 43. 1 illus.

France

A Flight of the Gyroplane at Villacoublay. M. Victor. Successful results obtained in flight tests of the Breguet-Dorand gyroplane. Les Ailes, December 17, 1936, pages 14–15. 1 illus.

Zigzags Through the Show. General tendencies discussed include: reduced dimensions; narrow fuselages; suppression of front turrets; transformation of large rear turrets and gunners cockpits into small lenticular flat turrets, or analogous arrangements indicating that the illusion of firing crosswise has been abandoned; suppression of dual controls; and alterations inspired by flying ships. The discussion covers the Breguet Vulture 462, Morane Saulnier 430, Mureaux 200, the Loire 46 and 250, Lioré et Olivier C.34 autogiro, Polish P.24, Fokker G.1, Russian airplanes, Bloch 131, Potez 63, Hanriot 220, Renault C.690, and the Koolhoven, and Letov exhibits. Unusual features and speeds are reviewed. Photographs illustrate different views of the Fokker G.1 rear gun turret and the armament located in the front of the fuselage with the covering removed and showing the two Madsen 23 mm. cannons, and two machine guns. A drawing of the Potez 63 three-seater pursuit shows the location of crew and equipment. Rev. de l'Armée de l'Air, December, 1936, pages 1391–1400. 8 illus.

Caudron-Renault C-720. Pursuit training airplane derived from the C-690 and powered by a Renault 140–155-hp. engine. Photograph only. Les Ailes, December 31, 1936, page 9. 1 illus.

The Drone-Trainer and the Elytroplan. Rougé Elytroplan tailless airplane stabilized by vertical disks and the new Kronfeld trainer. Photographs only. Les Ailes, January 7, 1937, page 1. 2 illus.

For the South Atlantic. A top speed of 180 m.p.h. at an all-up weight of 18 tons is expected of the new Lioré-et-Olivier LeO. 47 flying boat. Brief reference. Aeroplane, February 3, 1937, page 149.

Latécoere 582 Tested. At a gross weight of 12 tons the Latécoere 582 reconnaissance seaplane took off three times in an average time of 6 sec., and made three landings, all with full load, in a seaway of more than 3 ft. At 2180 meters, maximum speed is 279 km. per hour, and range is around 1800 km. Photograph only. Flight, February 4, 1937, page 120a. 1 illus.

Pilot Claisse Flies for Sixty-Three Minutes in the Gyroplane. R. Lallier. Performance of the Breguet-Dorand gyroplane in a test flight. Very brief. L'Aéronautique, December, 1936, page 322. 1 illus.

Potez 453 Seaplane. Single-seater catapultable seaplane equipped with a Hispano-Suiza 14 Hbs. engine has a maximum speed of 320 km. per hour at 3500 meters. Characteristics and performance. L'Aerotecnica, December, 1936, page 981. 2 illus.

Airplanes at the Paris Aircraft Show. R. Eisenlohr. Comments on the aircraft displayed. A. T. Z., January 10, 1937, pages 8–10. 9 illus.

The Paris Aero Show. H. Desbruères. Military, commercial, and private airplanes, seaplanes, autogiro, gyroplane, engines, equipment, and accessories displayed are reviewed. Photographs include the Morano-Saulnier 430, Koolhoven F.K. 55, Mureaux 190 C-1, Loire-Nieuport 250, Fokker G-1 (one view with covering removed to show two cannons and two machine guns), Potez 63, Hanriot 220, Dewoitine D. 510, Romano 80, Breguet 462 B. 4 Vultur, Bristol Blenheim, Farman 224 Centaure II, Amiot 341, Caudron Renault C. 640 Typhon, Russian ANT35, and the LeO. C.34 autogiro. Drawings of eight landing gears and six instrument board and controls are included. L'Aérophile, December, 1936, pages 266–274. 26 illus.

Safety Tests for the Potez 62. Fitted with Gnome Rhone K 14s engines and an all-up weight of 14,070 lb., the Potez 62 kept an altitude of 4500 ft. for one hour with one engine stopped, and with Hispano-Suiza 12 Xirs engines and at 16,500 lb. it maintained an altitude of 8400 ft. for one hour with one engine stopped. Brief reference only. Flight, February 4, 1937, page 129.

Germany

German Practice Today. The Henschel single-seater fighter and dive bomber sesquiplane (B.M.W. 132 650-hp. radial engine) has an auxiliary fuel tank located between the undercarriage legs. The Henschel low-wing monoplane for training and aerobatic work (Argus As 10C 240-hp. inverted vee engine) has a maximum speed of 174 m.p.h. The new Focke Wulf F.W. 58 bomber-trainer (two Argus inverted vee engines) differs from earlier types n having an enclosed cockpit for the front gunner which increases performance. Brief descriptions. Flight, February 4, 1937, pages 120c–120d. 3 illus.

The New Ha-139 Seaplane. Catapultable seaplane for the North Atlantic is powered by four Junkers heavy-oil 600-hp. engines and has a welded-steel tubular monospar which comprises the fuel tank. The floats are articulated at variable incidence. The seaplane has a cruising speed of 250 km. per hour and a range of 5000 km. Construction described. Les Ailes, January 21, 1937, page 7. 2 illus.

The Diesel-engined Blohm and Voss Hamburger 139 catapultable float plane is designed for use over the North Atlantic. It has a top speed of 185 m.p.h. and a range of more than 3000 miles. Photograph only. Flight, February 4, 1937, page 129. 1 illus.

Great Britain

General arrangement drawings of the Ensign-class monoplanes being built for Imperial Airways by Armstrong Whitworth. Span is 123 ft., length 110 ft., and wing area 2450 sq. ft. Small drawings only. Flight, February 11, 1937, page 142. 3 illus.

Branching Out. Hafner A. R. III "direct flight" gyroplane is now going through its final flight tests and coming well up to expectations. Its take-off is said to be almost ridiculously short and its angle of climb impressive. Photographs and editorial comment. Flight, February 11, 1937, pages 135–137. 2 illus.

Economic Range. Performance estimates for the Short-Mayo composite aircraft first gave approximately a cruising speed of 160 m.p.h., and a range of over 2000 miles with a payload of 1000 lb. The structure of the upper component has been found to be a great deal stronger than originally expected and it is now announced that the machine is likely to be able to carry 4000 lb. in certain circumstances. Range in still air is now estimated as 3500 miles. Brief editorial. Flight, February 11, 1937, pages 133–134.

The Four Winds. Types of Armstrong Whitworth Whitley, each with Tiger engines, have been designed. Brief reference. Flight, February 4, 1937, page 115.

The Miles Whitney Straight. H. A. Taylor. Wide speed range, wide range of approach angles, viceless characteristics and studied comfort are features of this low-wing two-place airplane. Powered with a 130-hp. D.H. Gipsy Major engine, the airplane has a top speed of 145 m.p.h. Flight performance described. Flight, February 4, 1937, pages 112–114. 6 illus. 1 table. Aeroplane, February 3, 1937, 6 illus.

Bombers Have the Edge. The Bristol Blenheim twin-engined bomber. A few comments by Professor Klemin. Scientific Am., February, 1937, pages 106–107. 2 illus.

The Four Winds. The British Air Ministry has made preliminary tests with the French Dewoitine D.510 monoplane having a Hispano-Suiza "moteur canon." Flight, January 28, 1937, page 94.

Miles Mohawk. Colonel Lindberg's British airplane which has a 270-hp. Menasco B6S engine. Design and dimensions. Aviation, February, 1937. 2 illus.

Battle Junior—Top of the Class. "Probably the fastest single-engined bomber in the world." New Fairey light bomber with Rolls-Royce Merlin engine of 1000-plus hp. is 6 ft. shorter in span than the Battle medium bomber, carries a lighter load, and has an undercarriage retracting inwardly instead of rearwards. Dive bombing is likely to be one of the new machine's main duties. Photograph only. Flight, January 28, 1937, page 94. 1 illus. Aeroplane, January 27, 1937. 1 illus.

A Study in Bombers. One view of a Fairey Hendon (two Rolls-Royce Kestrels), now coming through in regular series, and two views of the Boeing YB-17. Weight, overall dimensions, and engine horsepower of the Boeing are given with the comment that "the makers claim that it is the world's fastest bomber but we should like to match our Blenheim against it." Photographs only. Aeroplane, January 27, 1937, page 116. 3 illus.

HOLLAND

Fokker D21 Monoplane. The performance characteristics given for the D21 pursuit airplane apply to the types having a fixed landing gear and Bristol Mercury VII. Hispano 2-Ycrs. and Wright Cyclone R.1820 engine respectively. L'Aerotecnica, November, 1936, pages 878–879. 2 illus. 1 table.

The Fokker D.21 Single-Seater Pursuit. Armament, characteristics, and performance with the Bristol Mercury VII, Hispano-Suiza 12 Ycrs, and Wright Cyclone R. 1820-F.54, respectively. Rev. de l'Armée de l'Air, November, 1936, pages 1307–1309. 3 illus.

Koohoven F.K.-53 Junior Light Airplane. A. Frachet. Two-place monoplane equipped with a Walter Mikron 50/55-hp. engine and having a maximum speed of 150 km. per hour. Long description. Les Ailes, January 7, 1937, page 6. 3 illus.

ITALY

Piaggio P. 16 Trimotored Bomber. Bomber having a maximum speed of 400 km. per hour at 5000 meters. A few details of design, defensive armament, and characteristics with three Piaggio IX RC 610-hp. engines. Rev. de l'Armée de l'Air, November, 1936, pages 1309–1311. 4 illus.

The Nardi F.N. 305 Monoplane. Two-seater monoplane with a special high-lift arrangement is powered with a 180-hp. Fiat A70S engine and has a cruising speed of 305 km. per hour and minimum speed of 85 km. per hour. Long description with drawings illustrating the high-lift arrangement and retractable landing gear. L'Aerotecnica, November ,1936, pages 869–872, 6 illus. Les Ailes, December 24, 1936, pages 3, 1. 7 illus.

Three Italian Military Seaplanes. The M.F.4 catapultable seaplane is designed for reconnaissance and bombing, and has a folding wing, a Piaggio Stella IXR 610-hp. engine, and a maximum speed of 220 km. per hour. The M.F.6 two-place catapultable pursuit and reconnaissance seaplane is powered by a Fiat A-59 700-hp. engine and has a maximum speed of 290 km. per hour at 2000 meters. The M.F.10 catapultable two-seater pursuit and reconnaissance seaplane has a Fiat A-30-R 600-hp. engine and a maximum speed of 300 km. per hour at 3000 meters. L'Aerotecnica, November, 1936, pages 873–874. 3 illus.

JAPAN

A Mitsubishi Monoplane. Two Japanese airplanes ordered by the Japanese government railroad, one derived from the Mitsubishi Type 92 military reconnaissance airplane, and the other from the Nippon type 95-2 training airplane. Brief reference to characteristics. Les Ailes, December 10, 1936, page 5.

Some Recent Japanese Military Airplanes. Kawasaki C.5 three-place high-speed transport powered with a Kawasaki-B.M.W. VIII 600-hp. engine has a top speed of 335 km. per hour. It is said to resemble in form certain American single-seater pursuits and two-seater attack planes (Northrop in particular). The Kawanishi Navy 90-11 trimotored flying boat is a modification of the Short, is powered with three Rolls-Royce Buzzard 825-hp. engines, and has a maximum speed of 220-km. per hour. The Kawanishi Navy 94 three-place seaplane is powered by a Navy-91 500–600-hp. engine. The Aichi Navy 92 three-place bomber has a range above 1000 km. The Nakajima Navy 90 single-seater pursuit has a top speed of 310 km. per hour and is powered with a Kotobuki II 450-hp. aircooled engine. Few details only. Rev. de l'Armée de l'Air, November, 1936, pages 1311–1314. 5 illus.

POLAND

P.Z.L. 23/43 Airplane for General Purposes. A. Frachet. Two Polish all-metal three-place military monoplanes. The P.Z.L.-23 is equipped with a Bristol Pegasus VIII 660/680-hp. engine and has a maximum speed of 342 km. per hour at 4000 meters. The P.Z.L.-43 has a Gnôme-Rhône 14-N.01 950-hp. engine and a maximum speed of 370 km. per hour. The airplanes are designed for long-range reconnaissance, day and night bombardment, and aerial and ground attack. Construction, characteristics, and performance. Les Ailes, December 31, 1936, page 3. 2 illus.

R.W.D.-16 Light Touring Airplane. A. Frachet. Polish two seater monoplane powered by a Walter Mikron 50/55-hp. engine has a cruising speed of 120 km. per hour. Long description. Les Ailes, January 28, 1937, page 6. 4 illus.

U. S. A.

The Latest American Single Seater Pursuit. Curtiss P.36 equipped with a new Wright Cyclone 1000-hp. engine. Brief reference only. Les Ailes, January 21, 1937. 3 illus.

North American N.A.-16 Military Airplanes. A. Frachet. Four models, designed, respectively for training, general purpose, attack and bombardment, and pursuit, have been constructed for the U. S. Army Air Corps. The models are described in detail with characteristics and performance of each, and armament. Les Ailes, January 21, 1937, page 6. 2 illus., 1 table.

Notes on the American Military Aviation Industry. M. Jan-Kerguistel and M. P. Servel. Maximum speeds are given for the principal military airplanes now in service, including the Boeing P-26 and P-12-E, Curtiss P-6-E, A-8, and A-12 Northrop A-13 (also bomb load and machine guns), Douglas 0-43 and 0-46, Martin B-01 and B-12, and Consolidated P-30. Comments are made on Glenn Martin, Curtiss, Bellanca, Seversky, Eclipse, and Sperry products and production methods. The Curtiss and Loire 130, and the Seversky pursuit and Loire 21 and 250 are compared. Photographs include those of the gun turret and interior of the cockpit of the Martin B.10. Rev. de l'Armée de l'Air, November, 1936, pages 1221–1236. 8 illus.

Al Williams' Grumman G-22 Aerobatic Airplane. Specially-built high-performance Grumman biplane intended for aerobatic and inverted flying is powered with a 100-hp. Wright Cyclone engine and has a maximum speed of 290 m.p.h. at 12,000 ft. Construction, equipment, and oil and fuel system designed for extended inverted flying are described. Aero Digest, February, 1937, pages 46, 48. 3 illus., 1 table. Aviation, February, 1937, page 44. 4 illus.

Amphibious Gear Developed by Edo Aircraft. The aft 4 ft. of the described float is a separate removable section hinged at the deck and fitted with a Bendix shock strut which, by means of a linkage arrangement, provides the tail with 7 in. of oleo-sprung travel. The result is a combination wheel and skid on the transom. Aero Digest, February, 1937, page 73. 5 illus. Aviation, February, 1937, page 37. 4 illus.

Army Tests Old-New Type of Undercarriage. Brief reference to Air Corps tests of the tricycle landing gear on a Douglas amphibian, and the comment that Army officers look with favor on the tricycle type. U. S. Air Services, February, 1937, page 31.

Curtiss-Wright 19R American Airplane for Training and Combat. Construction and armament are discussed. L'Aerotecnica, November, 1936, pages 876–878. 3 illus.

Eight-Place Twin-Engined Beechcraft Model 18 with Jacobs or Wright Engines. Bimotored low-wing cabin monoplane has a semi-monocoque construction, a fully retractable landing gear and tail wheel, and a cruising speed of 167 m.p.h. Construction details and equipment. Aero Digest, February 4, 1937, pages 52, 54. 5 illus., 1 table.

New Bomber. Latest improvements for altitude and sub-stratosphere flying, as well as new type gun provisions and locations rendering the plane capable of defending itself from any angle of attack are features of the North American Dragon long-range bomber to be entered in the Air Corps competition in March. The fuselage is sufficiently large to house the largest bomb load provided for on any airplane to date. From three to five high-powered guns can be brought to bear on any point around the airplane. New type gun mounts permit the operator to work efficiently in high altitudes. Brief description. Aero Digest, February, 1937, pages 82–83. 1 illus. Aviation, February, 1937, page 41. 1 illus.

The New Rearwin Sportster. Models 7000, 8500, and 9000 two-place Sportster airplanes having maximum speed ranges from 115 to 125 m.p.h. Refinements in design described. Aero Digest, February, 1937, page 62.

Stinson Reliant for 1937. New four-five place Stinson Reliant airplanes. Design refinements of the five SR-9 models are described. Aero Digest, February, 1937, pages 60–62. 3 illus. Aviation, February, 1937, pages 35–36. 5 illus.

Various Notes. "The first of a fleet of twin-motored armor-plated 10-passenger bombers, designed for substratosphere flying, rolled off North American runways. Powered with 1250-hp. Wasp motors and fashioned of multiplated armor, the craft spun through a series of rigorous tests under the eyes of U. S. Army experts, and was declared qualified." Brief reference to N. A. Dragon. U. S. Naval Inst. Proc., February, 1937, page 285.

U. S. S. R.

Soviet Aviation Today. P. M. Magruder and L. Zacharoff. Current status of aeronautics in the U. S. S. R. including a historical résumé, advances and shortcomings of recent years, and constructional features and performances of a few airplanes during the past year. Other outstanding aircraft are listed, problems of passenger, mail, and express are taken up, capital construction and equipment are discussed, special applications of aircraft in industry and agriculture are outlined, and prevailing trends stated. To be continued. Aero Digest, February, 1937, pages 28–31, 48. 10 illus.

Aircraft Performance

The Technique of Water Flying—Seaplane Handling. D. J. Brimm, Jr. Four main types of "disembarking" points which the seaplane pilot is likely to encounter and technique of negotiating them. Continuation. Aviation, February, 1937, pages 28–29, 72. 4 illus.

Technical Notes. A curious experiment on the stability of an airplane in flight without the effect of propellers was carried out on the Loire 102 four-motored transatlantic flying boat. Brief reference. Les Ailes, December 31, 1936. page 3.

Precision Right and Left Turns. V. Simmons. Further explanation of triangulation for precision spirals, and details of the new marker system at Oakland Airport. Western Flying, February, 1937, pages 19–21, 4 illus.

Alighting Gear and Controls

Hydraulic Versatility. Method adopted for emergency lowering of the undercarriage in the event of failure of the hydraulic system (due to damage by gun fire or other cause) is one of the features of the Dowty hydraulic control system described. The pilot is provided with a single-lever control for operating by remote control the undercarriage and tail wheels, flaps, and gun-firing gear. An electro-mechanical indicator tells the pilot at a glance the position of the undercarriage and tail wheels and the angle of the flaps. Flight, February 4, 1937, page 125. 2 illus.

Aeronautical Hydraulics. Lockheed undercarriage jacks, flap control system, engine-driven pump, and "Airdraulic" shock absorbers developed by Automotive Products Co. Flight, February 11, 1937, pages 155–156. 3 illus.

Airships

The Airship and Its Place in Modern Transportation. H. Eckener. Experiences during ten demonstration trips with the Hindenburg carried out last summer across the North Atlantic, expenses of these trips, and advantages of the airship for regular transoceanic service over the North Atlantic. S. A. E. Preprint for meeting, January 11 to 15, 1937, 8 pages.

Aircraft Instruments

Acoustic Sounding and the Noises of Airplanes. G. Jacquet. Different airplane noises and means by which they may be reduced are discussed and a band filter suggested for the sound receiver used in acoustic soundings. Rev. de l'Armée de l'Air, November, 1936, pages 1236–1240.

Aeronautical and Navigational Instruments. G. W. H. Gardner. Observations on the more interesting aircraft instruments displayed at the recent British Physical Society's Exhibition, and avenues along which it is hoped that progress will continue. Automatic pilots, aircraft repeater compass, directional gyroscope, artificial horizon indicator, echo altimeter, sensitive altimeter, vertical speed indicator, true air-speed indicator, and sextants. Jour. Scientific Instruments, February, 1937, pages 52–56. 2 illus.

An All-In-One C. D. C. Latest Simmonds-Goudine course and double-drift calculator. Instead of making an actual vector "model," the course, track, and wind lines are separate and held together by the moving scale with its two rules. Brief description. Flight, February 11, 1937, page 150. 2 illus., 1 table.

The Virtual Dihedral of the Constantin Vanes. Constantin vanes used for the automatic piloting of airplanes. Results of experimental study of the transverse stability in flight and wind-tunnel tests. The tests were carried out on the Potez 56 transport. Les Ailes, December 24, 1936, page 6.

Air Transportation

Britain Bids for New Airways to Conquer. D. Sayre. Objectives of Imperial Airways in building up its airlines, past development, plans, for extension, equipment plans, and competition from the airlines of other countries. Aviation, February, 1937, pages 24–25, 69, 71, 75. 2 illus.

The Maybury Report. Conclusions and recommendations from the Maybury Committee's report on the development of civil aviation in the United Kingdom. Flight, January 28, 1937, page 95. 2 illus., 1 table. Historical review, existing conditions, and recommendations of the report. With a discussion by C. G. Grey. Aeroplane, January 27, 1937, pages 89–95.

The Rise of Air Transportation. R. M. Cleveland. Outstanding aircraft in use on the airlines of the world at present are briefly reviewed and a few details of aircraft planned for the immediate future are given. Scientific Am., February, 1937, pages 78–80. 3 illus., 1 table.

Civil Aviation in Russia. A. Biel. Airlines, airports, equipment used, aircraft industry, and personnel. Rev. du Ministère de l'Air, December, 1936, pages 1591–1611. 6 illus., 2 tables.

Trans-Atlantic Flight. L. C. Milburn. Development of transoceanic commercial aviation and features of the planes designed for this service (especially those of the Clippers and China Clipper), tests on "sea wings" or lateral stabilizers developed especially for ocean travel, and operation of modern flying aids employed in trans-oceanic service are discussed in the original paper but only referred to here. Very brief abstract of paper to be presented before the Detroit Section, March 16. S. A. E. Jour., Fenruary, 1937, page 61.

Airport Equipment

The Aerodrome Owners' Conference. Opening of the British Exhibition, and review of airport equipment, accessories, surfacing and finishing materials displayed. Aeroplane, January 27, 1937, pages 101–115, many illustrations.

Airports Exhibition High-Lights. Points of outstanding interest at the British Airports Exhibition. Flight, January 28, 1937, pages 86–93, 21 illus.

Specially Planned Modern Building for Final Assembly. New aircraft assembly building recently placed in service by Boeing Aircraft Company at Seattle to accommodate the largest type of landplane or seaplane such as the YB-17 bomber and the flying boats for Pan American Airways. Long description of building and equipment. Aero Digest, February, 1937, pages 32–34. 9 illus.

Device Speeds Tire Removal. Device perfected by United Air Lines to facilitate the dismounting of tires from airplane wheels. A few details. Western Flying, February, 1937, page 40. 1 illus.

Speeding Up Transport Maintenance. Tripod support for use while working on retractable landing gear, stand to enable mechanics to work on tail surfaces without standing on the fin or rudder, platform fitting into the landing-gear structure inside the nacelle, and wing stands. Servicing equipment used by T.W.A. Photographs and a few details. Western Flying, February, 1937, pages 14–15. 4 illus.

Miscellaneous Equipment

Equipment and Methods. Chambersburg pneumatic hammer, United Air Lines tire remover, DeWalt semi-automatic metal cutter, Hanniñ propeller straighiener, Braun, Dienhart, and Roberts engine heaters, and Champion corona-less spark plugs. Few details. Aero Digest, February, 1937, pages 74, 76. 6 illus.

Up Above the World So High. Bradley Jones. United Air Lines tests at altitudes of 16,000 to 22,000 ft. to determine the affect of high altitudes on passengers and pilots are referred to in a general discussion of the affect of high altitudes on human beings. U. S. Air Services, February, 1937, pages 10–12, 34. 1 illus.

Records and Shows

Digest of Recent Events. Record flights of Lieut. H. F. Klein (New York–Montreal), Seversky amphibian, Maryse Bastie (South Atlantic), Sinclair New York–New Orleans) and Hughes' (transcontinental). Brief references only. Aero Digest, February, 1937, page 86. 1 illus.

National Aviation Show. Review of exhibits. Aero Digest, February, 1937, pages 26–28, 88. General description. U. S. Air Services, February, 1937, pages 17, 19. List of events and displays. Aviation, February, 1937, pages 19–22. 17 illus. General account. Business Week, February 6, 1937, pages 38, 40. 1 illus. Exhibitors. Western Flying, February, 1937, pages 26.

Parachutes

Events Abroad—Austria. Parachute invented by J. Eschner enables the jumper to descend with his machine gun and even to fire it during the descent. Brief reference to this and to the training of parachute jumpers by the Austrian Aero Club. R. A. F. Quarterly, January, 1937, page 94.

Metals

The Ryan Drop-Hammer Process. F. S. Martin. New method of aircraft production perfected by the Ryan Aeronautical Company. Western Flying, February, 1937, pages 16–18, 23. 6 illus.

Heat Treatment

Ripoche Electric Furnace for Aeronautical Construction. Electric furnace used in the Farman factory for heat treatment of very long parts of duralumin. Rev. de l'Armée de l'Air, November, 1936, pages 1298–1302. 3 illus.

Non-Ferrous Alloys

Home-Grown Structural Materials. C. H. Desch. Magnesium and beryllium alloys as materials for aircraft. Mechanical properties of magnesium, wrought alloys, disappointing results with beryllium-magnesium alloys, silver as the most promising addition to standard magnesium alloys, magnesium alloys at high temperatures, and protection for the surface of magnesium-alloy propellers. Paper presented before the Royal Aeronautical Society with discussion following. The author is superintendent of the Metallurgical Department, National Physical Laboratory. Aeroplane, January 20, 1937, pages 72–74. Brief abstract. Flight, January 28, 1937, page 104. Metal Industry, January 29, 1937, pages 161–167. 6 tables.

The Magic Metal. Aero structures of beryllium-aluminum alloys will have nearly twice the strength of average high-grade steel, yet at only a quarter of the weight. Beryllium in aviation and sources of supplies covered in a general discussion. Aeroplane, Aeronautical Engg. Sup., January 20, 1937, pages 69–71.

Plastics

Synthetic Materials for Aircraft Construction. N. A. DeBruyne. Cord Aerolite and its application to aircraft construction. Special types of reinforcement provide both increase in stiffness and increased strength for a given weight in torsional or vertical shear in comparison with Alclad or plywood. Weight saved for an airplane using Cord Aerolite and having one ton gross weight is computed and advantageous applications of this material for cowlings, struts, bushing for control levers, and propeller blades are discussed.

Aerolite's property of absorbing vibration is compared with that of wood or metal. A method of making glued joints is described and wing-root fittings for Aerolite and wooden spars are illustrated. Results of tests made by Aero Research, Ltd., to apply this material to aircraft structures are referred to

The first part of the article deals with the chemical constitution and physical structure of Bakelite, its future possibilities, and properties of Cord Aerolite. A very long abstract of paper presented before the Royal Aeronautical Society is given in the first issue.

The second issue contains the discussion by H. E. Wimperis, M. Langley, W. O. Manning, R. A. Dutton, F. W. Lanchester, I. J. Gerard, C. D. Philippe, J. V. Connolly, and others on the subject of application of plastics to aircraft construction, as well as the author's reply. Aeroplane, February 3 and 10, 1937, pages 142–143 and 169–170. 5 illus., 3 tables. Shorter abstract and some of the discussion. Flight, February 4 and 11, 1937, pages 121–123 and 150–153. 9 illus., 2 tables.

Plexiglas in Aircraft. G. P. Young. Tough durable and light-weight synthetic resin of crystal-clear transparency, equivalent in light transmission to optical glass. Plexiglas may be formed into various shapes and pressures and has a softening point of 175° F. It is not affected by mineral oil, gasoline or water, but is soluble in organic esters. Properties and applications in aircraft. Aero Digest, February, 1937, page 50. 2 illus.

Propellers

Airscrews at the Paris Aero Show. B. Jablonsky. Radical changes in propeller designs since the 1935 exhibit are reviewed and the considerable contrasts in the designs of variable-pitch propellers now exhibited are pointed out. The deLevaud is said to be the only representative of the fully automatically controlled system. To facilitate the design of a compact hub, with closely approaching blade roots, it is suggested that manufacturers make their motors with flanges instead of crankshaft ends. The adjustable-pitch and variable-pitch types exhibited are compared and the advantages of the Chauviére wooden blades are discussed. This installment deals with general trends and is illustrated with photographs of the self-setting and manually-operated types of Gnôme-Rhône controllable-pitch propeller, working parts of the deLavaud, the self-setting Messier controllable-pitch, steel hub of the Jablo to take detachable wooden blades, and the hub for the detachable Schwarz-protected wooden blades. To be continued. Aeroplane, Aeronautical Engg. Sup., February 3, 1937, pages 139–141. 7 illus.

Source of Propeller Noise. W. Ernsthausen. Source of propeller noise was investigated on a model propeller and a study was made of the relation between the pressure and sound field, composition and directional effect of the propagated sound, and its influence due to obstructions in the vicinity of the propeller and the propeller blade speed. Report of the Electrophysics Department of the DVL. Luftfahrtforschung, December 20, 1936, pages 433–440. 24 illus., 5 equations.

Ratier Propeller Regulator. Automatic regulation by electrical contact which has been developed for the control of the Ratier variable-pitch propeller. Power is furnished by an electric motor placed in the end of the propeller hub, turning with it and connected at the root of the blade. Les Ailes, December 24, 1936, page 6. 1 illus.

Variable-Pitch Propellers. P. A. Richards. Geometric definitions, theory of operation, characteristic curves, calculations for adaptation and operation, general problem of propellers with variable parameters, calculated and experimental results with this type of propeller, forces exerted on the blade in operation, and different types of adjustable-pitch propellers (Hamilton, Ratier, Levasseur, Curtiss, Hele-Shaw, Smith, and Gnome Rhône). La Technique Aéronautique No. 141, 1936, pages 190–209 17 equations.

Engine Design and Research

Development of a Fuel-Injection Spark-Ignition Oil Engine. N. Fodor. The fuel-injection spark-ignition oil engine described is designed to operate on the same fuel as a Diesel engine and with approximately the same fuel economy, but with pressures throughout the entire cycle which would not exceed those of a gasoline engine of equal size and speed, designed for the same service. Engine developed in the oil-engine laboratory of the Allis Chalmers Manufacturing Company. A. S. M. E. Trans. January, 1937, pages 21–31. 26 illus.

Distribution of Heat Loss in Petrol Engines. W. T. David. Distribution of explosion-expansion heat losses, and the effect of speed upon heat loss. Discussion of article published in the December 25, 1936, issue. Engineer, February 5, 1937, pages 154–155. 6 tables.

High-Speed Diesel Engines. H. R. Ricardo. Development undertaken by the author since the war. Results of the early tests are compared with those obtained by the Royal Aircraft Establishment and firms on the Continent. The latter part of the development discussed is concerned chiefly with the design of Diesel engines for road vehicles and especially that of the Comet engine. Two forms of combustion chamber designed for fuels of the near future are referred to. The author prefers the sleeve valve for real continuous hard work. Paper presented before the British Association. Engineering, January 29, 1937, pages 136–138. 6 illus.

Fracture of Connecting Rods in Inline Water-Cooled Aircraft Engines. Lieutenant Churet. Poor behavior of antifriction bearing alloys, fractures due to fatigue of metal or to cracks on the connecting rods, fracture of piston pins, defects of the forked connecting rod and in the oil of the crankpins, and poor operation of the engine are given as causes for the fractures of connecting rods in those types of aircraft engines. Antifriction alloys used for bearings of aircraft engines are discussed in detail. The author considers that present bearings used in aircraft engines do not offer sufficient guarantees of safety and enumerates the characteristics of a good aircraft-engine bearing. Long article based on defects observed in these aircraft engines during operation. Rev. du Ministère de l'Air, December, 1936, pages 1567–1590. 9 illus.

The Modern Engine-Propeller Group. M. Precoul. Possibilities of stratospheric flight at 15,000 to 18,000 meters and the types of superchargers which will be required. Three- or four-stage centrifugal superchargers are said to offer an immediate solution. If the coefficients foreseen by Rateau can be realized, the turbo-compressor will be an easy solution with excellent efficiency. The Roots volumetric compressor appears more likely to be applied in the near future, particularly for high-powered engines.

Characteristics of the superchargers for the following engines are given: Curtiss Super Conqueror SV.1570 F., Wright Cyclone SR.1820 F.3, Hispano-Suiza 12 Ybrs, Gnôme-Rhône Jupiter VII, Rolls-Royce Kestrel 11.S, Gnôme-Rhône Titan 14 Kdr, and Bristol Mercury IV.S.2. The Farman, Rolls-Royce, Bristol, Roots, and Fiat superchargers are illustrated. Applications of the centrifugal, Rateau turbo-, and Roots volumetric superchargers to high-altitude flight are calculated. Rev. du Ministère de l'Air, December, 1936, pages 1517–1545. 20 illus., 2 tables., 25 equations.

Heavy-oil engines for aircraft are briefly discussed and characteristics are given for modern American, French, English, German, and Czechoslovakian engines of this type. Unlike the preceding article on superchargers, this discussion does not mention high-altitude flight. Drawings and photographs cover the 1200-hp. Deschamps, 286-hp. Zod, Rochefort pneumatic injection (in the test stage), 500-hp. Clerget 14 Fcs and its injector and injection pump, 150-hp. Jalbert (5 views), 530-hp. C.L.M. Junkers, 600-hp. Junkers Jumo 205, 730-hp. Napier-Junkers Culverin, and the Coateleu injector and its 600-hp. engine. Grouped in the characteristics table as United States designs are the Deschamps 1200-hp., Baltimore 1200-hp., Beardmore 500-hp., Continental 635-hp., Guiberson 240-hp., Packard 225-hp., N.A.C.A. 700-hp. and R. R. Condor 480-hp. heavy-oil engines. Rev. du Ministère de l'Air, December, 1936, pages 1546–1566. 19 illus., 1 table.

Junkers Diesel Motors and Supercharging. J. Gasterstaedt. Progress made by Junkers in the last five years toward the production of the light Diesel aircraft engine. The Jumo 206 now in the course of development has a cylinder capacity of 25 liters, will be much smaller than the Jumo 2.04, particularly in depth, as well as lighter in weight and more efficient.

The discussion covers: outstanding features of the Jumo 205; problems due to high gas pressure and rapid pressure rise in the cylinder; vibration; scavenging and charging; improvement in supercharging; the Junkers injection pump; problem of temperature variations in the combustion chamber, particularly in the pistons; design of Diesel motors for high-altitude flying; and attempt to utilize exhaust gases by means of an exhaust-gas turbine to drive a supercharger at high levels. A drawing illustrates a 2000-hp. Diesel with four crankshafts (6 ft. long, 3 ft. 3 in. high) in comparison with a 750-hp. Jumo 204. Paper presented before the Lilienthal Gesellschaft and translated from "Junkers Nachrichten." Aeroplane, Aeronautical Engg. Sup., February 10, 1937, pages 165–169. 12 illus.

Design of the Aircraft Engine in Russia. Comments of the designer of the A.M.-34 1200-hp. engine. Les Ailes, December 31, 1936, pages 9–10.

The Problem of Ring Sticking in Aviation Engines. O. C. Bridgeman. Ring sticking in aviation engines can only be controlled by continuous improvement in oil characteristics, by endeavoring to remove a greater amount of heat from the pistons, and by continued improvement in piston rings. Although ring sticking in many of these engines probably can be minimized by alterations in design, present indications point to the necessity for using compounded oils of high oiliness and stability if satisfactory ring performance is to be obtained in engines of higher horsepower per cubic inch displacement than those in use at present. Two very brief abstracts and reference only to discussion sent in by R. V. Kerley, Air Corps Depot, Wright Field. (Preprint was not obtainable.) S. A. E. Jour., February, 1937, pages 19, 32–33.

Trend in Aviation. "Engines developing 1000 to 1200 hp. are being installed in new military airplanes as well as transports. Research and development continues on Diesel engines for aircraft and on larger horsepower inline, Vee, and H-types for military utilization." Brief outline of engineering and technical advancements in the aeronautical field. From Tech. Engineering News, December, 1936. U. S. Naval Inst. Proc., February, 1937, pages 284–285.

Engine Manufacture

Connecting Rod Bores. British machine and fixture for machining nickel-steel aircraft-engine rods. Automobile Engineer, February, 1937, page 56. 1 illus.

Engine Testing

Bearing Metal Testing Machine with Dynamic Load. H. O. Heyer. The dynamic testing machine described reproduces the stresses encountered by bearings in service and was developed to test the suitability of bearing materials for the main bearings of airplane engines. The bearings may be so stressed that the forces vary as to magnitude and direction. Influence of the more or less intermittent load on the behavior of the bearings in service may be tested due to the variability of load distribution in the testing machine. Report of the DVL, Department of Materials. Luftfahrtforschung, January 20, 1937, pages 14–25. 30 illus., 1 table.

Some Results Obtained on the Cathode Ray Engine Indicator. E. M. Dodds. Although most of the pressure elements and circuits of the cathode-ray indicator developed are "perfectly satisfactory on normal petrol and Diesel engines, it has been impossible up to the present time to obtain a really satisfactory pressure-time card on the high-duty boosted aircraft engine, the main difficulty being due to the super position of mechanical vibration on the pressure-time diagrams." A satisfactory knock indicator produced is described and a few results given. C.F.R./aero-engine correlation and a method of indicating detonation without engine attachment are discussed. The knock indicator described in the first part of the article employs a pressure element of the capacity type, consisting only of steel and mica and diagrams representing either pressure against time or rate-of-change of pressure against time are obtained directly from the element by means of a straightforward amplifier. Jour. Royal Aeronautical Soc., February, 1937, pages 132–139. 11 illus.

Visual Stress Machine. Photoelastic visual stress machine designed by Bristol Aeroplane Company and now in regular use in their engine laboratory. Photograph shows the stresses revealed in a model of a master rod, where operating stresses cannot even be approximately calculated. Brief description of method of using such a machine. Automobile Engineer, February, 1937, page 67. 1 illus.

Engines

Alfa Romeo 115-1 Engine. New inverted aircooled engine developing 185 hp. at 2100 r.p.m. is described. L'Aerotecnica, November, 1937, pages 880–881. 1 illus.

Alvis Activities. The first Alvis 1000-hp. will soon begin type tests of the British Air Ministry. Brief reference. Aeroplane, January 27, 1937, page 122.

The Four Winds. The British Air Ministry is reported to be experimenting with the Cambridge exhaust-gas analyzer with a view to its adoption on Service aircraft. Brief reference. Flight, January 28, 1937, page 94.

Aircraft Engines at the Paris Show. F. Wittekind. Comments on the engines displayed with table of characteristics. A. T. Z., January 10, 1937, pages 11–15. 7 illus., 1 table.

The Alfa-Romeo 115-1 Engine. Six-cylinder inline inverted engine developing 185 hp. at 2100 r.p.m. Characteristics only. Les Ailes, January 21, 1937, page 7.

American Airplane Engines. Specifications are given for a great number of airplane engines manufactured by 15 American, six British, one Czechoslovakian five French, five German, and two Italian engine companies. These tables are followed by others giving specifications for automotive Diesels and other heavy-oil engines designed for motor buses, trucks, rail cars, and boats. Statistical tables for airplane-engine production in 1936, and production by types, and a third table headed "7800 Airplane Engines produce 1,500,000 Hp." are given on pages 288–289. Automotive Industries, February 27, 1937, pages 332–339 and 288–289. 6 tables.

A Dagger—And Part of Its Sheath. Production version of the 725/805-hp. Napier Dagger III as mounted in a large batch of Hawker Hector Army co-operation biplanes being built by Westland Aircraft. The hot and cold air intakes and the forward portion of the cowling with the new streamlined entry chutes for cooling the air are pointed out. Photographs only. Flight, February 11, 1937, page 136. 2 illus.

The Garuffa Heavy-Oil Engine. Nine-cylinder radial heavy-oil engine. Brief illustrated reference. L'Aérophile, December, 1936, page 274. 1 illus.

High Initial-Pressure Lubricating System for Aero Engines. The high initial oil-pressure system described enables Bristol engines to develop their full power with perfect safety as soon as they are started. In a winter flight test in a Bristol Bulldog, the throttle was opened wide as soon as the cold engine was started and a full-power climb to 10,000 ft. was commenced at once. When the engine is cold, a restrictor, fitted in the pipe connecting the relief valve to the oil tank, will produce a higher pressure in the bypass pipe. Oil pressure in the delivery pipe to the crankshaft will also increase until it becomes sufficient to open both the main relief valve and the sprayer valve. Oil is sprayed directly on the crankpin bearing but as soon as the oil warms up the sprayer closes. Engineering, January 29, 1937, pages 128–129. 1 illus.

Jap Designs Air Engine. New type radial aircraft engine designed by M. Fukutaki is said to have shown no signs of cylinder wear after a 50-hour test run developing 315 b.hp. at 2300 r.p.m. The engine is a nine-cylinder supercharged unit with a 5:3 compression ration and is rated at 285 b.hp. at 2300 r.p.m. Brief reference only. Automotive Industries, February 6, 1937, page 175.

Junkers Heavy-Oil Aero Engines. J. Gasterstedt. Progress made in the last five years since the engine was first adopted for use in aircraft. Outstanding features of construction of the Jumo 205, scavenging and charging process, relation between injection and combustion, temperature variations in the combustion chamber, particularly in the pistons, and design of heavy-oil engines for high-altitude flight are discussed. An output of between 1500 and 2000 hp. at a specific weight of less than 0.5 kg./hp. for future designs is anticipated. Engineer, February 5, 1937, pages 167–169. 14 illus.

Menasco Six-Cylinder Inverted Aircraft Engine. Drawing only. Automotive Industries. February 6, 1937, pages 197–198. 2 illus.

Power of the Future. Dagger E.108 fully supercharged, two Bristol aquila sleeve valve, Pegasus (special), Kestrel (special), Perseus Pr. E. (IS), two (Pegasus) models with two-speed blowers, a new moderately supercharged Pegasus and two "fullblown" Pegasus, a moderately supercharged Merlin and two Mercurys, and the Siddeley Tiger having a two-speed supercharger. Brief reference to the latest aircraft engines built for the British Air Ministry. Flight, February 4, 1937, page 132.

The New Petter Engine. Two-stroke Diesel engine embodying a novel principle known as the harmonic induction principle. Instead of the use of crankcase compression, pumps, or blowers, the wave motion set by exhaust gases in the exhaust pipe is utilized. Present production is confined to industrial engines. Automobile Engineer, February, 1937, pages 65–66. 4 illus.

Russian Light Aircraft Engines. Table of characteristics of the WA D2 30-hp. and WA D3 45-hp. Russian engines. Brief. A. T. Z., January 10, 1937, page 22. 1 table.

Startling Engine Claims. Aspin aircraft engine of high thermal efficiency now being built has four cylinders opposed in pairs, and is to develop 80 to 100 hp. at a normal r.p.m. of 5000 and a maximum of 8000 r.p.m. Weight-power ratio will be about 0.81 lb./hp. High thermal efficiency is based on the complete scavenging of the exhaust gases and the controlled turbulence of the charge. Brief description. Flight, February 11, 1937, page 154. 1 illus.

Parts and Accessories

The Bellem Injection Pump. Pump for direct injection of fuel in a Diesel engine under high pressure, eliminating all pipes. The piston of the injector is controlled by a cam like a valve. Application to a Cummins engine is referred to. Les Ailes, January 28, 1937, page 8. 3 illus.

Getting Up on Cold Mornings. High initial oil-pressure system evolved by the Bristol Company so that their motors can be run at full power from the moment they are started. The system is essential for the new Short Empire flying boats. So long as the oil is cold an auxiliary supply is sprayed directly onto the crank-pin bearing but as soon as the oil gets warm, the viscosity and quantity of the bypassed oil is decreased and so the pressure created by the restrictor is automatically reduced. The whole system is quite automatic, requires no attention, and adds practically nothing to the bulk or weight of the engine. Aeroplane, February 3, 1937, page 141. 1 illus. Automobile Engineer, February, 1937, page 62. 1 illus. Flight, February 18, 1937, pages 174–175. 1 illus.

Simple Engine Heater Developed. Heater developed by B. E. Braun for use by Chicago and Southern Air Lines during cold weather is attached to the engine directly on the nose cowling. Brief description. Western Flying, February, 1937, page 38. 1 illus.

Technical Notes. Brandenburg fuel supply device for internal-combustion engines permits the use of the whole range of fuels from gasoline to gas oil. Vaporization of all the combustibles is accomplished by a very powerful depression created between the inlet valve and the piston during suction stroke, and part of the heat of the exhaust gas is utilized for vaporization. Brief reference. Les Ailes, December 24, 1936, page 5.

Engines of the Fokker G-1 are elastically mounted with Dynaflex suspension. Brief reference. Les Ailes, December 24, 1936, page 5.

Buyers' Log Book. Berry fabric rejuvenator, Permutit-Ranarex and Hays-Orsatomat exhaust analyzers, Dupont Neoprene synthetic rubber, and Hasler TEL tachometer. Few details. Aviation, February, 1937, page 49. 2 illus.

Fuels and Lubricants

The Higher Alcohols. A. R. Ogston. One of the most suitable methods of utilizing the properties of alcohol will be by supplying it to the carburetor from a separate tank installed in the aircraft. Very brief letter discussing the use of alcohol blends as aircraft fuel. Reference is made to a special British carburetor exhibited at the Paris Show and having provision for a separate and optional supply of alcohol. Aeroplane, January 27, 1937, page 125.

The Effect of Knock Intensity on Fuel Knock Ratings. N. MacCoull. Effect of knock intensity on the knock ratings of four widely different fuels was investigated by a group of C. F. R. members. Report given in the original article indicates that the type of bouncing pin used may affect the changes in knock rating due to variations in knock intensity resulting from changing the compression ratio. Very brief abstract of paper presented before the Annual Meeting. (Preprint not available.) S. A. E. Jour., February, 1937, page 29.

Ethyl Fits the Job. J. Geschelin. Research laboratories of the Ethyl Gasoline Corporation in Detroit. Basic types of investigation which are a part of the everyday Ethyl program, personnel, equipment, examples of the research program, commercial and future developments. Brief reference is made to tests for rating aviation fuels and to the unusually severe laboratory engine conditions of the Army Air Corps. Automotive Industries, February 20, 1937, pages 250–255, 8 illus.

Selection of Oils for High-Output Aircraft Engines. A. L. Beall. (See TECHNICAL DATA DIGEST, December 15 issue for review of preprint of this paper.) The paper and discussion following are given, the latter entitled "Suggests One-Cylinder Engine Tests," C. F. Baker. "Believes Author's Method Only Sure Way," C. M. Larson. "Outlines Research Program on Bench Laboratory Tests," Lt. C. F. Coe. S. A. E. Jour (Trans.), February, 1937, pages 48–56. 9 illus, 1 table.

Synthetic Decanes as High-Antiknock Fuels. P. L. Cramer and J. M. Campbell. Preparation of the diamylenes from the isomeric amylenes and amyl alcohols by means of sulfuric acid has been investigated to determine synthesizing decanes suitable for use as high-antiknock fuels. Decanes derived from dimethylethylcarbinol, trimethylethylene, and unsym-methyl-ethylene have antiknock characteristics which are comparable to those of isooctane. Industrial & Engineering Chemistry, Ind. Ed., February, 1937, pages 234–237. 2 illus., 1 table.

Aircraft Radio

Aero Radio Digest. American Airlines directional communication antenna installed at Grand Central Air Terminal, and radio meteorographs used for experimental flights into the stratosphere are briefly described. Aero Digest, February, 1937, page 68. 2 illus.

Portable Learadio. Light-weight portable transmitter and receiver for field use. The unit provides day and night two-way communication up to 300 miles by radio telephone and over even longer distances by use of telegraphy. A gasoline engine and generator are included in the ground equipment. Aviation, February, 1937, page 43. 1 illus.

Practical Aspects of Radio Navigation of Aircraft. H. W. Roberts. Radio range beacon system, aircraft radio direction finding, and ground radio direction finding are described and practical aspects of radio navigation by means of each are considered. Aero Digest, February, 1937, pages 56, 58. 5 illus.

Ellipsoidal Radio-Electric Arrangement for Protecting Airplanes from Collisions. Method developed by M. J. Valoris consists in the automatic bearing and hertzian range finding of transmissions of safety made by airplanes designed to navigate in fog. The airplane protected transmits modulated waves and is placed in the center of a radioelectric field. Les Ailes, January 28, 1937, page 8. 5 illus.

Aerial Navigation with a Radio Compass. J. L. Houssin. Busignies RC-5 L.M.T. automatic radio compass for aircraft is an automatic direction finder which indicates the direction of radio stations which are located anywhere around the airplane and from which signals can be received. Design, installation, and operation are described in detail. The manner in which the radio compass furnishes indications and the way in which these indications can be combined with those from magnetic compasses are explained. Use of the radio compass both as a direction finder and as a navigation instrument is discussed. L'Aéronautique, December, 1936, pages 323–329. 14 illus.

Principle and Theory of a New Design of Automatic Radio Compass for Aircraft. A. B. Damyanovitch. Theory, design, and operation of the Busignies automatic radio compass for aircraft with an illustration showing the location of the parts in the airplane. L'Onde Électrique, January, 1937, pages 5–28. 11 illus., many equations.

The Radio Compass. H. Busignies. Applications to aerial navigation regarding situation of the apparatus, precision, disturbances, night errors, utilization, and application to landing without visibility are discussed. Other methods of radio navigation are compared with the Busignies system including direction-finding apparatus on board the plane and on the ground and radio beacons. Applications of the radio compass in France and other countries are referred to. L'Aérophile, January, 1937, pages 14–20. 10 illus.

Meteorology

New Radio Balloon Instrument Measures Thickness of Clouds. New device which enables scientists on the ground to measure the height of the clouds, their thickness, and the altitude to which an airplane must climb to come out on top has been developed by H. Diamond, W. S. Hinman, Jr., and F. W. Dunmore of the Bureau of Standards in cooperation with the Navy. Brief description. Science News Letter, February 27, 1937, pages 134–135. 2 illus.

Air Forces

Al Williams Makes a First-Hand Study of Military Aviation Abroad. "America is in a bad way when it comes to comparing our air power with that of the major countries of Europe." The author urges this country to develop Diesel engines for bombers and liquid-cooled engines for streamlined airplanes.

In Germany one plant visited could turn out 50 complete Diesel engines every 24 hours, while another could produce about three bombers every 24 hours, and, by slightly expanding the present production method, could manufacture 20 airplanes every 24 hours. Italy can produce about 2000 complete fighting and bombardment airplanes a month. Mass production is England's problem. Extracts from newspaper articles. U. S. Air Services, February, 1937, pages 13–14. 2 illus.

BELGIUM

Events Abroad—Belgium. Conclusions reached by a mixed Belgian commission formed for the study of national defense. Brief. R. A. F. Quarterly, January, 1937, pages 92–93.

BRAZIL

News of the Week in Pictures. Avro 626 (275-hp. Armstrong-Siddeley Cheetah V) trainer biplane for Brazil can be used for a variety of purposes, the rear cockpit being adaptable for gunnery, prone bombing, photography or radio, while provision is made for instrument flying and message collection. Photograph only. Flight, February 11, 1937, page 137. 1 illus. Aeroplane, February 10, 1937, page 160. 1 illus.

CANADA

Canada and War in the Air. Wing Commander S. G. Tackaberry. Canada's contribution in the last war and the advance of Canadian aviation since 1918 are reviewed and Canada's part in the next war is predicted by a member of the Royal Canadian Air Force. Difficulty of supplying sufficient equipment is foreseen as the greatest obstacle to the rapid expansion of air forces in Canada in the event of war, due to the fact that practically all of the service equipment (aircraft, radio, and photographic) is imported from England.

Problem of supplying suitable materials for the manufacture of aircraft and engines in Canada, necessary cooperation from Imperial authorities in building up a Canadian aircraft industry, and the problem of constructing training aircraft in Canada in quantities for war training are discussed. R. A. F. Quarterly, January, 1937, pages 40–47.

Canada's Air Force. 1937 estimates calling for doubling of man power. Personnel increase only is given. Aviation, February, 1937, page 57.

Dominion Air Forces. Canada is allotting $11,750,000 for the Royal Canadian Air Force in the coming fiscal year. Increase in strength and aircraft given in brief editorial. Flight, January 28, 1937, page 85.

Handsome Increase in Air Force Estimates. Increase in estimates for the Royal Canadian Air Force, and the expansion of personnel and equipment which it will furnish. Brief editorial. Canadian Aviation, February, 1937, page 4.

EGYPT

The Inscrutable Smile. Hawker Audax with Panther engines for the Egyptian Army Air Force. Photograph only with caption calling attention to the Vickers gun mounting transferred outboard and cowling grooved to clear the engine. Flight, February 11, 1937, page 147. 1 illus.

FRANCE

In Competition with Large National Organizations What Independent Firms Will Exist? Four aeronautical firms remaining free, and the formula of the French Arsenal. Les Ailes, January 28, 1937, page 11.

The Organization of Our Aeronautical Industry under the Rule of Nationalization. Objectives of the French nationalization of its aeronautical industry, and the situation at the present time. Les Ailes, January 21, 1937, page 11.

Reorganizing the French Air Force. French Naval aviation is now divided into two divisions, the L'Aéronautique Navale, permanently placed at the disposal of the Navy and including all aircraft engaged in naval operations, both shore and ship based, and the L'Aviation de Co-operation Maritime de l'Armée de l'Air, which is an integral part of the Armée de l'Air but specifically adapted for operations in liaison with the Navy. The Air Ministry retains complete control relating to the supply of flying equipment for these divisions. A new department of the Air Ministry is the Service de l'Armament divided into four sections dealing with guns, bombs and munitions, fire and bomb control, and administration. Two groups of Air Infantry, parachutists, are being formed. A brief description of the reorganization. Aeroplane, February 3, 1937, page 130.

Events Abroad—France. Air display at Le Bourget in July, nationalization of war industries, democratization of flying and establishment of a college for advanced study of questions relating to national defense. Brief notes on these events. R. A. F. Quarterly, January, 1937, pages 89–92.

GERMANY

Events Abroad—Germany. Device for obtaining an unlimited supply of fresh air for the ventilation of gas-proof chambers. Few details only. R. A. F. Quarterly, January, 1937, page 93.

GREAT BRITAIN

Air Defence. Criticisms of the slow progress made in the expansion of the R.A.F. and the reasons given for the deficiency. Conflicting figures on present strength, given by O. E. Simmonds, W. Churchill, and Sir Inskip, and the vulnerability of factories and power stations to bombing are discussed. Quotations from debate in the House of Commons. Flight, February 4, 1937, pages 116–117.

The Air Defence Debate. The British Air Ministry is still aiming at 1750 aircraft but they will not make up as many squadrons as at first reckoned. Lag in the program for the production of "air frames" and the present number of squadrons are discussed in an editorial. Flight, February 4, 1937, pages 109–110.

Air Defence Progress. Eighty-seven squadrons of the R.A.F. have now been formed and thirteen of them are still on a one-flight basis. Others of the squadrons are over strength in personnel, with a sufficient number of aircraft for training purposes. By the end of March, 100 squadrons formed and 124 squadrons brought into existence are anticipated. A few comments made by the Minister for Co-ordination of Defence in a debate in the House of Commons, also referring to reasons for the lag in aircraft production. These reasons are further discussed in an editorial. Engineer, February 5, 1937, pages 149 and 161.

Combined Manoeuvers at Singapore. An account of the combined operations which were held on February 1, 2, and 3, and which were designed to exercise all the units of the British Navy, Army, and Air Force in testing the defence of the Port of Singapore. The attacking force consisted of two cruisers, five destroyers, submarines and a submarine depot ship, the aircraft carrier Hermes with a simulated total striking force of over 100 airplanes, and a detachment of the Johore military forces. The defending Force consisted of the regular garrison at Singapore, eight squadrons of the Royal Air Force with their attendant bomber transport machines, and a flight of the Singapore Auxiliary Air Force Squadron, four destroyers, four submarines with a submarine base ship, and detachments of the Straits Settlements R.N.V.R. Aeroplane, February 10, 1937, pages 161–162. 2 illus.

Keeping Them Up. Suggestions for bringing the British unapproved firms directly into the expansion scheme by giving them repairs on aircraft which cannot be made by the squadron. Brief editorial. Flight, February 4, 1937, page 111.

On Letting Down the Empire. C. G. Grey. Lord Swinton's expansion scheme as a dismal flop, and the building of the North American 16 type airplanes in Australia for the R.A.A.F. are considered in a typical Grey discussion. The author quotes an Australian paper as saying "Australian Defence Authorities have long felt that British military planes—designed to meet the strategic needs of a small country with neighbors as potential enemies—are not suitable for Australian use. They consider that the defence needs of the United States, with its great distances and long coast line, correspond more closely with those of Australia, and that consequently American planes are more suitable here." Mr. Grey considers that the N.A. 16 will be well out of date by the time it is produced in Australia. Aeroplane, February 3, 1937, pages 135–138. 3 illus.

Why the R.A.F. Has Not Expanded. "Six firms are turning out bombing aircraft. One has an order for 320, of which 40 were promised for Christmas and not one has been delivered, the second has turned out none so far; the third has about 30 ready for completion but no motors have arrived for them, the fourth has none delivered but ten nearly ready; the machines of the fifth are not up to specification; and those of the sixth are being delivered according to schedule." Debate in the House of Commons on Air Defence and the lag in aircraft production. Aeroplane, February 3, 1937, pages 128–130.

The Aircraft Industry and the R. A. F. Wing Commander E. L. Howard-Williams. "What matters that we produce faster aircraft than our neighbors if those aircraft cannot use their guns nor drop their bombs accurately?" The prospect of the fast twin-engined bomber is discussed and the suggestion made that a proportion of each type of bomber be maintained with emphasis on the fast twin.

In regard to the merit of armament the author believes that the striking power of the R.A.F. can be increased at this time by research and development in armament rather than in aircraft and engines. Hitting power, problem of aircraft modification, the value of the 500-hour type test, importance of reducing the lag between design and supply, the problem of mobility, and the problem of supply are discussed.

The author considers that stored reserve aircraft should be erected with engines in and flown every month in order to enable aircraft reserves to be available immediately to replace casualties at the outbreak of war. He suggests that the manufacturers themselves should be called upon to maintain this reserve within the confines of their own premises. R. A. F. Quarterly, January, 1937, pages 14–24.

On Butter. C. G. Grey. A typical Grey discussion criticizing recent statements of Foreign Minister Anthony Eden and taking the part of Germany in regard to its preference for guns instead of butter. Aeroplane, January 20, 1937, pages 62–64.

Royal Air Force Expansion. New units and stations, personnel required by April of this year, and aircraft production. A few notes only. R. A. F. Quarterly, January, 1937, pages 86–87.

Royal Air Force Mobility. Flight-Lieutenant V. Q. Blackden. Reply to "The Mobile Squadron on Imperial Routes." For every overseas command one "air transport" squadron is recommended which would consist of eight passenger-carrying and four freight-carrying aircraft similar to those used by Imperial Airways, these units to be equipped with land planes, flying boats, or both. Suggestions are made for reducing to a minimum the personnel to be taken in a reinforcement squadron, and the problem of proper training and equipment for such a squadron is discussed. R. A. F. Quarterly, January, 1937, pages 25–27.

ITALY

Events Abroad—Italy. Newly formed unit for the protection of the population against aerial attack, air force expansion and finance, the air force in Ethiopia, and the hydrogenation process applied to fuel production. Brief references only. R. A. F. Quarterly, January, 1937, pages 95–96.

JAPAN

Events Abroad—Japan. Japan is sending a small mission to Germany to study airship design, pilotage, and business management. Brief reference and list of accidents in military and civil aviation during the three months ending June 30, 1936. R. A. F. Quarterly, January, 1937, page 99.

SWEDEN

Events Abroad—Sweden. Reorganization of the Swedish air force. A few notes only on the units, personnel, training, and the present equipment. R. A. F. Quarterly, January, 1937, pages 96–98.

U. S. A.

Aviation and Its Place in a modern Defense Program. Major General O. Westover. "Any measure to create a separate Air Department of the Government, or even a separate setup of aviation within the War Department, would at this time be a step backward." Request to the Air Defense League for indorsement of the War Department's efforts to develop the Army Air Corps, including the G. H. Q. Air Force and all Corps and Army Aviation Units.

The need for a balanced program for the Air Corps, study of the number of men and the amount of the other components necessary to a balanced Air Force, recently completed, and ways in which the League can be of assistance in the promotion of this program are discussed. U. S. Air Services, February, 1937, pages 15–16, 34.

Complete the Military Program. Congressional appropriations to complete the military program are urged in a brief editorial. Aero Digest, February, 1937, page 25.

Events Abroad—United States of America. Brief notes on Air Corps orders for Seversky single-seater pursuits and Curtiss YA-18 airplanes, giving the maximum speed of the former as around 315 m.p.h. at 11,000 ft. A press release of the War Department is quoted which refers to the contract for fifty Stearman primary training biplanes and to the maximum and cruising speeds; climb, and range which these airplanes must attain. R. A. F. Quarterly, January, 1937, page 99.

Reconnaissance for the Attack and Bombardment Squadrons. Abstract and discussion (in French) of an article entitled "G.H.Q. Air Force Observation" from the October 1 issue of Air Corps News Letter. Rev. de l'Armée de l'Air, December, 1936, pages 1401–1403.

A Rum Omission. Emergency equipment packed in the parachutes used by the flying personnel of the United States Army Air Corps in the Panama Canal Zone. Brief reference to contents. Aeroplane, February 10, 1937, page 157.

U. S. S. R.

Aviation of the U. S. S. R. M. Proust. The first issue covers: a historical review of development; the organization; distribution, control, and character of the aeronautic industry; research and types of airplanes and engines developed; materials used in aircraft and engines and Russian resources (steels, bronzes, aluminum alloys, magnesium alloys, wood, plastics, and synthetic rubber).

The concluding article takes up the problem of fuel, factory supplies, military aviation (organization, character, power, airplanes and other equipment, personnel, and doctrine), civil aviation (organization, character, air transportation, private aviation, gliding), and aviation records achieved. L'Aérophile, December, 1936 and January, 1937, pages 275–280 and 6–13. 5 illus., 4 tables.

YUGOSLAVIA

Rolling Down to Ragusa. Latest Hawker Fury (745-hp. Rolls-Royce Kestrel XVI) built for the Yugoslavian Air Force. Photographs only. Aeroplane, February 10, 1937, pages 156–159. 4 illus.

Air Warfare

Bombardment of a Movable Target. Captain D. D'Auerstaedt. Bombardment of a boat with the aid of the S.T. Aé. bomb sight. Method of bombardment in the face of a fictitious wind, of a boat moved in a rectilinear uniform motion, mathematical properties of the curve L, trajectory imposed on the bomber in this method, practical experiments, and the possible transformation of the bomb sight which will facilitate the employment in the method proposed. Rev. de l'Armée de l'Air, December, 1936, pages 1337–1360. 17 illus.

Naval Warfare Tomorrow. Hector C. Bywater. "Unless operating from floating bases, aircraft are, and bid fair to remain, absolutely powerless to solve any problem arising out of Pacific strategy." "To all appearances, the naval strategy of the United States is even less likely to be modified as the result of progress in aviation. It is difficult to see how the paramount naval problems confronting the Unites States, namely maintenance of strategic control over the Eastern Pacific and security of communication with the Far East, including the Philippines, can be either complicated or simplified by development of air power." Army Ordnance, March-April, 1937, pages 266–268. 1 illus.

The Pursuit Remains Unsettled, More than Ever. Criticism of an article by M. Odier in the September issue entitled "The End of the Pursuit," The fugitive and the pursuer, maneuvers, fire from multiplace and single-seater pursuits, and combat are discussed and reference made to the Hispano-Suiza "moteur canon" which is illustrated. Further remarks by M. Odier are included. Rev. de L'Armée de l'Air, November, 1936, pages 1205–1220. 6 illus.

The Defence of Berlin. "Modern bombers would find it difficult to make much of an impression on Berlin." Opinions of British visitors to the German Flying Corps are quoted in a brief editorial. Flight, January 28, 1937, page 84.

Disarmament and the Prevention of War. Flight-Lieutenant C. W. Rugg. Limitation of the horrors of air warfare, the desirability of its attainment before war itself can be eliminated, and disarmament for the prevention of war are considered. R. A. F. Quarterly, January, 1937, pages 48–50. 1 illus.

Views on Air Defence. By the Authors of "Air Strategy." Rougeron's doctrine of "Bombardment Aviation" is discussed and "anti-Rougeron" fighter airplanes are described. Improvements in anti-aircraft gunnery, bombs, and characteristics of various types of aerial projectiles, and the various phases of a strategic bomb raid, such as bomb attack, approach, and navigation, are covered.

The section devoted to anti-Rougeron fighters, deals with their speed and armament, the need for massive use of high-initial-velocity shell-firing machine guns in specially designed aircraft, and high performance fighters. The two types of fighters recommended for use by the strategic air force are the light single-seater fighter equipped with two large-bore machine guns and anti-aircraft bombs, and the destroyer, carrying a crew of two to three, its main armament being a high-initial-velocity cannon. Attention is called to the hitherto unexploited possibilities of bombing attack on aircraft. R. A. F. Quarterly, January, 1937, pages 1–13. 1 table.

Armament

Can the Bombardier Protect Himself by Towing Torpedoes from the Airplane? P. Melon. When on night bombing expeditions, the bombardier can fire a torpedo towed by the airplane if attached and during day bombing he can protect the airplane by throwing grenades by means of a launching device described which the author considers very efficient. The problem of a control of the fuse to insure explosion at a convenient distance from the airplane must be solved first. The first issue deals with the towing of torpedoes and the second discusses the problem of throwing grenades from the airplane and a method of mounting the grenade releasing mechanism. Les Ailes, December 24 and 31, 1936, pages 5 and 7. 2 illus.

Projectiles for Combat between Airplanes. M. A. Brissot. General properties of projectiles for airplanes (different categories of projectiles, their effectiveness, and ballistic qualities), and the four types of projectile (solid, incendiary, explosive, and time shell) are described. Rev. de l'Armée de l'Air, December, 1936, pages 1323–1336. 1 illus.

Book Review

Ride on the Wind, by FRANCIS CHICHESTER; Harcourt, Brace and Company, New York, 1937; 286 pages, ill., $2.50.

For the wide circle of readers of adventure stories here is another book of the kind that stimulates minds fatigued by normal routine existence. From the days of Robinson Crusoe, of Jules Verne, and Robert Louis Stevenson, there has been a demand for tales of experiences imaginary or real which has led to the publishing of a wide variety of such literature. Apparently there are many readers who get a thrill from reading about aeronautical flights which take them to the romantic and less well-known parts of the earth's surface. If the paths of all the flights which have resulted in books could be traced on a globe they could cover almost every continent. Chichester had the ambition to fly around the world in a D. H. Moth. He flew from London to Australia, and this book is really a diary of his flight as far as Japan, where he wrecked his small airplane by hitting some wires on his take off.

When asked why he was making the flight he frankly said it was to secure material for a book. With this purpose in mind he kept careful notes and was alertly observing everything which might be of interest to readers. The result has been a book which gives a vivid impression of the coastlines of Australia, New Guinea, the Philippines, China, and Japan. And who knows how soon these routes of pioneering exploits may become regular commercial air routes?